INCENDIES EN FORÊT

(FOREST FIRES)

By

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Translated by

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Deputy Conservator of Forests

Appraisement of Damage.

CONTROVERSIAL.
PROTECTIVE MEASURES. VERIFICATIONS.
PRINCIPLES OF APPRAISEMENT.
RATES. - ESTIMATION OF VALUES AND AREAS.
DISLOCATION OF WORKING.
ACCESSORY AND INDIRECT DAMAGE.
SPECIMEN REPORTS. TABLES, ETC.

"Behold how great a matter a little fire kindleth."
St. James.

"A little fire is quickly trodden out;
Which, being suffered, rivers cannot quench."
3 Hen. VI, iv 8.

" Momento fit cinis: diu sylva."—*Sen.*

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TRANSLATOR'S PREFACE.

PRIOR to the publication of M. Jacquot's erudite work, no book dealing comprehensively with forest fires had been produced.

That such a work was required is proved by the fact that a second edition was soon called for. The original edition was published early in 1903 and the second (from which this translation has been made) issued in 1904.

It is not expected that the work can be applied fully at present in India, but here and there, over restricted areas, in plantations, nurseries, etc., claims to compensation could be strengthened by its support, and in many cases the damage could be estimated under the rules suggested.

The avowed intention of the author was to assist private owners rather than professional foresters in calculating the extent of damage and in supporting their claims before a court of law, in case of fire in their forests.

Apart from the estimation of damage and reclamation of indemnity, the work cannot fail to be of great interest to foresters, especially in a country like India, where fires are so constant a danger. It brings forward a host of minor sources of damage which one is too apt to overlook, even if they are not absolutely ignored. Many suggestive facts applicable to our controversial problems will be met with.

The author has taken pains to support himself by authority, and in the body of the work will be found copious extracts from the writings of others. In the original book, the works consulted are tabulated, and no less than 125 authors are mentioned. It has not been thought necessary to reproduce this list in the present volume, but in the text several of the authorities are quoted.

In order to avoid unnecessary complications, the figures quoted by the author are retained in terms of French coinage and measure. To facilitate conversion, a comparative table of French and English coinage and measures is appended to this preface.

A *résumé* of the Indian laws and rules connected with forest fires, also has been thought useful.

Owing to difference in legal procedure, it has been difficult to find suitable English equivalents in some cases; this

also applies to certain forest and trade terms; for example, *parquet*, here meaning a court of justice and in most cases the court charged with the initial enquiry in case of fire, and which issues orders for further enquiries, valuations, etc. No better term than "court of enquiry" could be found. *Ensouchement, écobuage*, etc., are also not easy to express in English. In several cases the French word is shown in brackets. For *ensouchement* no translation has been attempted; the word itself is used, and it is explained in a footnote. For these shortcomings the translator must here apologise.

The book was reviewed in the issue of the "Indian Forester" for March 1906 by Mr. F. Gleadow, Conservator of Forests, and it is mainly at that gentleman's suggestion that this translation was undertaken.

It remains only to add that M. Jacquot's work has received high approbation and was the subject of eulogistic reports before the International Agricultural Congress held at Rome from the 13th to the 17th April 1903. The following resolution was adopted: "Serious damage is occasioned in forests by the frequency and gravity of fires. These injuries are not always appraised on a rational system. Certain indirect prejudicial effects, such as those concerned with the soil-covering, are generally overlooked. This Congress hopes that they will not be lost sight of in the future, and that with an eye to the protection of wooded tracts, equitable and precise rules, *such as those put forward in M. Jacquot's work,* should serve as a basis for the estimation of the damage done."

Comparative table of French and English coinage and measures.

French.		English.		Indian.
1 franc = fr.	=	10 pence	=	10 annas.
1·25 „ (approx.)	=	1 shilling	=	12 annas.
25 „ „	=	1 pound sterling	=	15 rupees.
1 kilogramme = kg.	=	2·2 lbs. avd.		
1 quintal = 500 kg.	=	1100		
1 metre = m	=	39·37 inches.		
1 cubic metre = C. M.	=	35·32 cubic feet.		
1 stère = 1 stacked C. M.	=	35·32 stacked cubic feet.		
1 hectare	=	2·471 acres.		
1 are = 0·01 hectare	=	119·6 square yards.		

French breast-height measure is conventionally recognised as 1·30 metre = 51·18 inches or 4 feet 3-1/5 inches.

INDIAN FOREST LAW IN RESPECT OF FIRES.

It is interesting to compare the law in India in regard to forest fires with the law in France, as indicated in Chapter I.

Section 25 (*c*) of the Indian Forest Act of 1878 reads: "Any person who kindles, keeps or carries any fire except at such seasons as the Forest Officer may from time to time notify in this behalf, shall be punished with imprisonment for a term which may extend to six months or with fine not exceeding Rs. 500 or with both, in addition to such compensation for damage done to the forest as the convicting court may direct to be paid."

Section 21 (*b*) and (*c*) of Act V of 1882, Madras Forest Act, is similar. Under Section 22 of the latter Act, Government may, in addition, suspend the exercise of all rights in the forest burnt and close it to grazing. Section 23 of the same Act lays down that all persons exercising rights in a reserved forest or permitted to remove forest produce therefrom, are bound to perform certain acts and give assistance in case of fire.

Section 26 provides certain powers to make rules for the protection of unreserved forest lands against fire.

Section 63 (*c*) empowers the Local Government to make additional rules "generally to carry out the provisions of the Act." No such rules have been made in the Madras Presidency (January 1908). In other Presidencies, however, advantage has been taken of Section 75 (*d*) of the Indian Forest Act, which is worded similarly to Section 63 (*c*) of the Madras Act, to promulgate certain additional rules. The chief ones are reviewed below.

In the Central Provinces, the following rules have been made:—

I.—Any person desirous of clearing by fire any standing forest or grass land within 3 miles of any reserved forest shall observe the following rules:—

(1) He shall give notice of his intention to burn at least one week beforehand to the nearest Forest Guard, Forester or Ranger.

(2) He shall clear a fire belt at least 30 feet broad on that side of the area which he proposes to burn which is nearest to the reserved

forest in such manner that no fire can spread across such belt.

(3)—He shall take care not to burn when a high wind is blowing.

II.—Any person desirous of burning on land within one mile of a reserved forest, any wood, grass weeds or other inflammable matter, shall collect such material into heaps and burn it heap by heap in such a manner that the fire shall not extend to the surrounding area or endanger the reserved forest.

III.—Any person collecting inflammable forest produce such as grass and bamboos, on land adjoining a reserved forest, and any holder of a permit to collect such produce from a reserved forest shall stack it in an open space at such reasonable distance from the forest as the Divisional Forest Officer may by general or special orders prescribe, and shall isolate the stack in such manner that if they take fire the fire shall not be able to spread to the surrounding area or endanger the forest.

IV.—Camping places along the boundary of and within the limits of a reserved forest will be cleared and set apart by the Divisional Forest Officer for the use of travellers, a list thereof being published annually, and except on such camping grounds no fires shall be lighted within or along the boundaries of a reserved forest. All persons using the camping grounds shall light any fires they may make for cooking or other purposes, in such a way as not to endanger the reserved forest or any building, sheds or other property on the camping grounds and before leaving they shall collect in the centre of the camping ground all inflammable material which is to be left behind and shall carefully extinguish all fires.

V.—The carrying of burning wood, fire-brands, or torches along the boundary of any reserved forest is prohibited between the 1st November and the 30th June or such earlier or later date as may be notified by the Divisional

> Forest Officer under Section 25 (*c*), with the previous approval of the Conservator. Smoking is similarly prohibited between 1st November and 30th June within a reserved forest, save at an authorised camping ground.

The rules in other provinces are similar; the chief points of disparity are as follows:—

Berar law of 1886 amended in 1891.

Rule 1.—No distance from the State forest is mentioned, the wording being "Land communicating with any State forest of class A or B." Notice of intention to burn must be given in writing. The fire belt need only be 15 feet wide and the fire should be set against the wind, and the burner "must provide himself with sufficient assistants, as regards men, to prevent the fire from crossing the line—and not leave the scene of the fire until all danger of the fire crossing the line shall have passed."

Rule II.—Again distance from the forest is not mentioned, but the words "in the proximity of any State Forest of class A or B" are used.

The rules of the United Provinces in Rule I restrict the distance to one mile and do not impose the clearing of a fire belt. The number of assistants when burning must not ordinarily be less than ten. The rule adds "after firing he shall extinguish any fire smouldering in the stumps or heaps of rubbish within 100 yards of the boundary of the reserved forest."

Rule II refers to land within 100 yards.

In Bengal, Rule I refers to land "near a reserve forest and in a locality from which such fire would be likely to endanger the reserve." The fire belt must be at least 20 feet wide.

Rules II and III speak of "land adjoining a reserved forest."

For the Punjab, the following miscellaneous rule has been promulgated:—

"The setting of fire to forest grass, brushwood or other combustible substances in a manner calculated to destroy or injure existing supplies of timber or fuel, may be absolutely forbidden."

Perhaps the most noteworthy difference between the law in France (and, it is believed, in most European countries)

and that of India, lies in the responsibility of railway companies for fires caused by sparks from locomotives. In France the companies have to pay damages and are entirely responsible, whereas in India such a demand would probably provoke as much derision as consternation.

LONDON;

April 5th, 1908.

INTRODUCTION.

Numerous fires occur in the forests of France. Considerable conflagrations, affecting whole woods, have become almost chronic in the Landes, as indeed they were in Provence until 1870. Small fires take place every year throughout the country; they assume large proportions from time to time: notably in Fontainebleau. In certain regions fire is the chief cause of anxiety and has necessitated special laws. Every year, large areas in Gascony are overrun: from 1869 to 1871, 36,000 hectares, valued at 16,000,000 francs, were destroyed.

In 1893 the disaster embraced an area of 46,551 hectares, with a loss of 9½ millions of francs. Seventeen thousand and ninety-four hectares were burnt in 1898; and 14,000 in 1899. Some authorities have assessed the damage at 15 millions of francs in a single year.

In the United States of America, an average loss of 675 millions of francs has been calculated. In Algeria, in 22 years, the area traversed by fires surpassed 900,000 hectares.

Fortunately these exceptional figures are encountered in a few countries only, but the real significance of the facts can only be apprehended by taking the administrative and not the economic point of view, since fires are ubiquitous. Indeed, the International Congress of Sylviculture of 1900 accepted M. Delassasseigne's proposition, expressing the earnest desire that the authorities of the several States should adopt, without delay, the necessary measures to put a stop, as far as possible, to the disastrous fires which destroy forests.

Each conflagration being followed by a report and an estimate of the resulting damage, one expects to find that by force of the multiplicity of fires, a manual of well-defined rules, a regular code of forest fires, has been evolved. This, however, is far from being the case. Not even in the special forest schools is the subject thoroughly threshed out. From the technical standpoint, but a single author (Puton) has broached the subject in a remarkable thesis, but in insufficient detail. Other writers have indicated, more or less vaguely, the precautionary measures to be adopted, and sketched the methods of valuation of damages in particular

circumstances, but so perfunctorily that little impression remains after a perusal of their works; some have even formulated erroneous conclusions. In short, nothing definite has been achieved. If, after long search, one does indeed happen upon a passage referring to forest fires, one finds that it does not apply to the particular case under consideration, or, if it does, the exposition of the procedure to be followed is diffuse, incomplete or inaccurate. Others, before us, have commented on the vague character of certain publications, skilful and highly considered though their authors may be. This hiatus, and on the other hand, the few lines that have appeared here and there, demonstrate necessity of a substantial treatise, summing up if not all possible contingencies, at least those occurring most frequently.

Had this work been limited to calculations of valuation it would have been little more than a hand-book of formulæ. Its aim, however, is more ambitious: it details the systems most advocated with their consequences, comments upon them and advances considerations hitherto overlooked; the solutions are discussed, problems are probed and hitherto unpublished theories are put forward. Thus, all necessary data in support of arguments and valuations are brought together in a single complete work.

The author's sole ambition is to assist proprietors, timber merchants, land agents, communal mayors, instructors, students at agricultural colleges, lawyers, railway companies, arbitrators or judicial appraisers, and even foresters, who are in difficulty through want of experience or forgetfulness of formulæ. This review, unlike that of Puton, does not include all phases of forest valuation; nevertheless, the methods are guides to trustworthy principles in all transactions relating to forests. They may serve to assess the damage done by troops, notably in young plantations; a far from rare occurrence during manœuvres. The book may be consulted for the settlement of the terms of compulsory acquisition, temporary concessions, and generally in all cases of injury to forest crops, such as breakage of reserved trees and through delay in the felling of coupes.

The list of persons to whom the book is intended to appeal justifies the form given to it. For professional foresters, portions are redundant, but this was necessary in the interest of the uninitiated. It is desired to sum up all the vexed questions bearing on the subject and give definite

and unambiguous rules to be followed in practice: In short, to present a compendium of forest fires. The elementary character of some of the paragraphs is intentional; the numerous readers discouraged by the excessive conciseness of certain authors, who introduce abstruse subjects without preamble, were kept in mind. For their sakes we were compelled throughout to proceed from the simple to the complex, thus facilitating a grasp of an otherwise difficult subject. It is, therefore, with set purpose that, abandoning all idea of harmonious composition, explanations have been multiplied and remarks have been reiterated in different form, in order to ensure their retention. Mathematical demonstrations can scarcely lay claim to fascination; the aim has been, therefore, to make them as lucid as possible.

Our object is to assist casual estimators, who are often ignorant of procedure; it is not our desire to instruct the inhabitants of the "fire zone," well versed in such appraisements. Only after vainly awaiting a similar work from their pens, have we decided to publish a work composed some years back.

The arguments followed in the work demonstrate the necessity of probing to the bottom of things and of submitting them to a searching and detailed analysis. Why should sylviculture not adopt the processes employed in other sciences to arrive at the truth? In common with natural philosophers, astronomers......the forester is entitled to apply the precision of mathematics to obtain the best results from his material observations. "Science is bound in honour to face boldly and without hesitation any problem set clearly before it."[1] In matters pertaining to sylviculture, the arbitrary cannot be excluded altogether. We have endeavoured to reduce it to a minimum by basing our figures on Working Plans in force, or, failing that, on established custom.

Following our Master, M. Broilliard, we are jealous of "the excessive intrusion of mathematics in forest matters," and are persuaded that observation should be the forester's chief guide. However, it is one thing to *manage* a forest, which is a matter of experience, and quite another to *estimate* the money-value of the results of the exploitation.

This has been recognised by the author of *Traitement des bois* ("Management of woods" by M. Broilliard). "Nevertheless, it is advisable to make oneself acquainted

[1] Sir William Thomson.

with the procedure of estimation, the rigorous principles upon which it is founded and the method of their application."

The following study is in part a statement of problems, a recapitulation of formulæ; consequently, it is hardly of an attractive nature. Our object, however, is utility; our intention is to assist, not to please. It is hoped that full allowance will be made for the difficulty of a pioneer work.

NEUFCHATEAU;

1st January 1903.

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CHAPTER I.—GENERAL PRINCIPLES OF ESTIMATIONS.

PART I.

JUDICIAL AND ADMINISTRATIVE.

CHAPTER I.—FRENCH LAW AND PROCEDURE.

1. Laws: woods in general.—Whoever *wilfully sets fire* to a forest even though indirectly and by any instrumentality whatsoever shall be punished with rigorous imprisonment under Article 434 of the Penal Code.

Article 458 of the Penal Code has a more general as well as a stricter application than the Forest Code. It provides punishment by fine for all unintentional incendiarism of forests by diverse agencies, notably through fires or lights carried or left burning without sufficient precautions, etc.

Excepting when a fire has been lit within 100 metres of a forest, the person responsible can escape punishment if he can show that the fire of which he is the involuntary author arose in spite of his vigilance and was due to fortuitous circumstances beyond his control.

Excepting where fire has been lit within the 100 metres limit, which in itself is a legal proof of want of caution, the onus of proof of imprudence or negligence lies with the prosecution.

Under this article, provided that a forest fire has actually occurred, a wide responsibility is imposed and it can be enforced in cases which are not covered by the Forest Code. On the other hand, if evidence of unintentional incendiarism is insufficient it is always open to the Court to inflict the punishment provided by Article 148, whenever the special acts forbidden by it can be proved against the accused, specially if they were performed within the 200 metres zone prescribed. Under Article 148 of the Forest Code the carriage or lighting of fires inside or within 200 metres of forests is prohibited. This prohibition is particularly aimed at graziers, right-holders and adjoining owners; it does not, however, preclude an owner from lighting a fire in his own woods at a distance of over 200 metres from neighbouring ones. This Article does not admit extenuating circumstances, excuses or even coercion; whereas the Penal Code does.

Any person who refuses or neglects to assist in case of fire is punishable under Articles 475 and 478 of the Penal Code.

Articles 1382 to 1384 of the Civil Code entitle owners to damages. Burning of sods is prohibited in the neighbourhood of forests under Article 10 of the law of 28th September, 6th October 1791; it is, however, actually practised in many localities under authority of rights of user or of administrative orders.

In accordance with Article 29 of the Criminal Procedure Code the officer in charge of the forest submits a copy of the enquiry report on a fire direct to the Court of Enquiry at the earliest possible date, before registration. The original is sent to the Conservator.

The law of 22nd December 1789—8th January 1790 imposes on the district (*département*) administrative officers the duty of safeguarding the public against fire spreading from a burning forest.

Under the laws of 16th-24th August 1790, 19th-22nd July 1791, and 5th April 1884, Municipal Councils are authorised to enforce measures to prevent accidents and to watch over the general safety. Such measures are sanctioned under Article 471 of the General Code.

Fires, like clearings, may cause inundations and, therefore, regulations with regard to rivers are necessary (see Section 120, *infra*).

The beds of unnavigable and unfloatable streams (Article 3) as well as of those that can carry drift wood (Article 30) are declared to be the property of bordering owners, by the law of the 8th April 1898. The beds of streams practicable for vessels or rafts, however, are deemed public property (Article 34). In combination with Article 641 of the Civil Code, Article 1 of this law specifies an indemnity to downstream proprietors should the utilisation or the diversion of rain water affect the right of common usage.

2. Laws: woods administered by the State.—For the purposes of legal action the regulations are classified into:—

(*a*) *General provisions applicable even to owners on their own property.*—Various ordinances are promulgated in Article 149 of the Forest Code under which right-holders refusing to render assistance in case of fire in the woods

wherein their rights may be exercised may be prosecuted. Such refusal is made the subject of a special report to the Court of Enquiry.

Article 151 of the Forest Code forbids the erection of lime and cement works and of brick and tile kilns within or at less than one kilometre from a forest, without the special permission of Government.

"Though permission to erect buildings within the prohibited zone is deemed to carry with it the right to light fires inside them, this implied right does not extend to the grounds attached, for instance in land within 200 metres of a forest." (M. Guyot).

In the tract of the "Maures et de l'Esterel" the lighting and maintenance of fires are regulated by the law of the 19th August 1893, which imposes restrictions on private owners.

Measures for the prevention of forest fires in Algeria are prescribed in the laws of 17th-19th July 1874 and 9th December 1885.

The last 3 laws contain special rules, particularly relating to the management of relief measures, occurrence reports, counterfiring, prohibition of grazing on the areas burnt, penalties and responsibility.

They are specially devised for the prevention of certain acts by the forest owner himself, whereas Article 148 of the Forest Code is directed against outsiders.

In Germany, Police regulations prescribe the creation of fire screens along railways where these traverse pine forests.

(*b*) *Provisions concerning acts of outsiders only.*—Under Articles 38 and 42 of the Forest Code purchasers of coupes are forbidden to establish charcoal-pits or to light fires except at the places indicated by the forest authorities.

It is under Article 148 of the Forest Code that Forest Officers usually proceed. (*Vide* Section 1, *supra.*) In practice considerable lenity is exercised in favour of private owners who light fires inside their own coupes within 200 metres of a forest under Government management. This toleration is reciprocal. "These acts of restraint, tacit or otherwise, have the effect of tempering the rigour of Article 148" (Extract of letter of the Director General of Forests, dated 19th September 1829).

Usually compensation only is levied in cases of conflagrations arising through a fire lit at a greater distance than 200 metres from a forest. Such cases fall within the jurisdiction of the Civil Courts unless there is definite proof that the damage is the result of a rash or negligent act.

3. Standing orders.—The same division into 2 classes made in the last section is necessary here.

(*a*) *General provisions applicable even to owners on their own property*:—In the pine forests of the South and the oak coppices combined with field crops in the Ardennes, and under all circumstances where the public security requires it, Prefects (*préfets*) are empowered to issue resolutions prohibiting and regulating the use of fire during certain seasons and these orders are binding even on private owners.

An order of the Minister of Finance, dated 14th July 1841, empowers the prefect to allow sod-burning (*écobuage*), under certain special conditions, in lands within 200 metres of a forest (Circular 507—Old series).

The burning of débris after coppicing (*Sartage*) within 200 yards or inside the limits of forests managed by Government can be carried out only with the sanction of the forest authorities.

"When permission for sod or débris burning has been granted prosecution under Article 148 or 458 can be resorted to only if no permission was granted in accordance with the order of 1841, or if the prescribed conditions have not been adhered to."

Under Article 471 of the Penal Code the Prefect of the Ardennes is authorised to issue orders to regulate the burning of débris in coppice coupes, and Mayors are empowered to prohibit the lighting of fires at certain seasons in special tracts or to impose special precautions.

Burning of heather is regulated in the Landes tracts by a prefectorial order, dated 17th May 1843, amended in 1856 and on the 8th October 1862, and in the province of Gironde by prefectorial orders of 1809, 1810, 1824 and 11th July 1859.

Prefectorial standing orders for the regulation of shooting in the provinces of Gironde, Landes and Lohet-Garonne prohibit the use of inflammable wads in pine forests.

In these same forests smoking is forbidden by the order of the Prefect of Gironde, dated 11th March 1889.

(*b*) *Provisions concerning acts of outsiders only.*—The working of charcoal-kilns is regulated in the Gironde by

prefectorial orders of 15th September 1899 and in the Landes by those of 12th September 1899.

By virtue of a departmental order issued by the Minister of Posts and Telegraphs on the 19th July 1882, subordinate Forest Officers are exempted from obtaining the customary countersignature to their telegrams when communicating with their superiors in case of fire. This privilege is not reciprocal: superior officers are bound to have their telegrams countersigned by the Prefect or the Sub-Prefect.

4. **Circular orders.**—Under the order of 23rd March 1821, the Guard (*chef de cantonnement*) must repair without delay to the locality where a fire has broken out, first sending an intimation to his superior officer.

The names of persons refusing assistance must be recorded in his occurrence report. Circular No. 146 (old series) draws attention to Article 29 of the Criminal Procedure Code. In his Circular of 19th August 1884, the Director of Forests orders that all fires starting in forests under Government management must be reported to him by means of short office notes. In case of serious disaster telegraphic intimation must be given to the Director on the very day of the occurrence, followed, with the least possible delay, by a special detailed report.

This last order is modified by Circular No. 416, dated 16th January 1890, but only as regards the Conservator, who is exempted from bringing insignificant fires to the notice of Government. Rangers and Divisional Officers (*Inspecteurs*) must report all fires.

Circular No. 572 of 25th January 1900 prescribes that in case of fire caused by a railway engine in Government forests, the local forest officer shall record all the connected circumstances, specially those which establish the responsibility of the railway company; after which he must communicate with the local representative of the company and arrange with him without delay to make independent valuations of the damages. Should the railway officer decline to comply the matter must be referred to Government.

The joint report is submitted by the Conservator to the prefect who in turn forwards it to the minister of agriculture. The latter fixes the indemnity to be paid by the Company.

Some Conservators insist on the same procedure being observed in regard to communal forests.

In certain provinces the Conservator is instructed to report the occurrence of fires to the prefect or to his deputy. This regulation is now rarely observed except in important cases.

II.

Prosecution by the Forest Administration.

5. Action taken by Forest Officers is restricted to the application in the Forest Code.—Forest Officers represent the State and Communal Bodies in forest matters. In criminal prosecutions, however, their powers are limited to offences quoted in and punishable under the Forest Code. When the estate affected is not under State control their jurisdiction ceases. They possess greater right to action in Civil Courts; this will be discussed in Section 10.

6. Further limitation of power to prosecute for incendiarism.—These limited powers of criminal prosecution are further restricted when the facts of the case bring it within the cognisance of the Common Law. Thus, should a fire result from a breach of Article 148, the latter offence is eclipsed by the graver one of accidental incendiarism or crime. In such case, theoretically, the court of criminal enquiry alone has power to take action and Forest Officers are no longer empowered to prosecute.

Should the Public Prosecutor refrain from action because he deems the conflagration unimportant, or the guilt of the accused appears insufficiently established, or for any other reason, the Forest Administration retains the right of filing a suit under Article 159 of the Forest Code, in which case only such punishment as is prescribed by this latter code can be inflicted.

Moreover, even should the Public Prosecutor take action by virtue of Article 182 of the Criminal Procedure Code, the Forest Administration is at liberty to claim damages under Article 148 or any other Article of the penal laws applicable to the case. An old practice, now abandoned, held that in the causing of a fire there were two distinct offences and that Article 458 of the Penal Code may be aggravated by Article 148 of the Forest Code. At the time that this view found favour the Attorney-General prosecuted under Article 458 and the Forest Administration independently sought the application of Article 148.

Once the case is presented before the tribunal the Public

Prosecutor is forced to come to a decision. Here lurks an element of danger as he may pronounce for acquittal or the accused may be acquitted in spite of the Public Prosecutor's views. In order to escape any counter-claim for damages, the Forest Officer, in addition to a claim to pecuniary reparation, should prefer a supplementary application for a fine under Article 148. Thus, should the charge of accidental incendiarism fail, there remains the simple offence of maintaining fire inside the forest or within the prohibited zone.

Though the accused be acquitted of the fine he may nevertheless be mulcted of an indemnity. Thus, when the accused is a minor and not responsible in law his father is civilly responsible under Article 206 of the Forest Code, and failing production of evidence to the effect that the act complained of was beyond his control, he may be condemned to pay damages and costs.

When the Court is convinced of the necessity it may modify the charge and give the facts such interpretation as may appear to conform more with the truth as ascertained during the enquiry, and may substitute for the section quoted by the Public Prosecutor or the Forest Officer prosecuting, such other as will correspond with the facts of the case.

7. **Fires caused by a railway engine.**—The concession granted to railway companies tacitly implies permission to carry fire in the forest, hence they are not liable to the fine imposed by Article 148 of the Forest Code. In case of fire they are liable only under common law. "When there is no evidence of want of proper precaution or of neglect they are only held liable to make amends for damage done, in accordance with Article 1382 of the Civil Code.

On the other hand, should carelessness or neglect be proved, such as, for instance, faulty construction of the engine, or excessive stoking, the driver or fireman concerned is liable to the penalty prescribed by Article 458." The onus of proof of carelessness or neglect rests with the prosecution :—the Public Prosecutor or the Forest Officer.

In Government forests the damages are estimated by the local Forest Officer and the railway Section-Officer independently (Circular No. 572).

A similar procedure has been recommended for communal forests, but in this case the joint report would be submitted to the Prefect and transferred by the latter to the

Mayor concerned on whom would devolve the direction of all further steps for obtaining payment of the indemnity from the railway company. This procedure is objectionable and commends itself only when no offence can be traced. The duty of claiming damages from railways properly falls on Forest Officers in their capacity as managers of communal forests.

8. An offence report must be prepared for every fire caused by a railway.—As no specific injunction has been laid down in the above-quoted instructions, it has sometimes been considered unnecessary to prepare an occurrence report, whereas, on the contrary, that should be the first step. If the Forest Department will not prosecute, or, at least, is not empowered to do so when unable to effect an amicable compromise, no town council would venture on litigation when the injury occasioned is not of a very serious nature. So long as the fire has not consumed wood to the value of several hundred francs the affected municipality, knowing the cost of legal proceedings, will not take the matter into court. The Company, on the other hand, well-advised in this direction, will pay only under compulsion.

The duty falling to the share firstly of the Forest Officer and then of the Mayor will be no easy task if not supported by a formal offence report. It is not for them to negociate with the representative of the railway, who may be located far away, and who without the expenditure of any very great perspicacity, may greatly delay matters by raising a series of objections or even by passive obstruction, to the detriment of all concerned except the railway he represents. What influence will a Range Officer (*garde général*) or the delegate of a village community be in a position to exert in a case of this nature? Unless the Company tenders an indemnity of its own accord—an eventuality as unlikely as it would be meritorious—it would be sheer waste of time.

9. Railway companies subject to common law.—Some Forest Officers refuse to prosecute railway companies under the pretext that there has been no intention to cause injury. This objection has no foundation and Articles 148 and 458 do not even allow of the question being raised. The latter is aimed at one of the rare offences against the Penal Code which does not admit the absence of evil intention as exculpatory.

Moreover, the Act of 22nd March 1806 empowers Conservators to hold enquiries in case of offences detected in the

act; this applies to fires, and, indeed, the code itself permits prosecution.

All the articles of law quoted above, excepting Article 434, make no mention of intention. They are formal and explicit and their application is clear whenever injury is caused even involuntarily.

In the report of the proceedings of the Parliamentary Commission appointed to enquire into the projected law for protection against fires in the region of "Maures et Esterel," the compiler, making no exceptions whatever, declares railway companies responsible for fires caused by trains passing over the permanent ways. Responsible here means amenable to law and liable to sentence by at least a Civil Court.

The best way of asserting this responsibility is by means of an occurrence report.

Finally, in case of negligence why deal differently with a railway company than with a private person? Should the owner of a field bordering a forest employ agricultural machines worked by steam or gas, or if a traction engine or automobile pass along a highway through a forest and damage results, indemnity would be claimed under Article 148 of the Forest Code or Article 458 of the Penal Code. Why then should they not be applied to railways in similar circumstances?

No laws are repealed by the special regulations affecting railways. According to Dalloz: "provisions regulating the carrying or maintenance of fires without sufficient safeguard apply equally to trains. What is prescribed for locomotives applies also to fires caused by any other steam-driven machines."

Summarising.—A Forest Officer hardly has the right to grant a privilege to a company without rhyme or reason. In any case the interpretation of an administrator, whose voice will be silent in a few years, cannot affect the application of formal and permanent laws. It is preferable, therefore, to mete out the law equally for all. While showing due consideration for an equitable company, whose representatives are equally the victims of the accident occurring under their responsibility but without their participation, let us still claim our rights.

The amount of the indemnity being settled, a notice is served on the railway Section Officer, who pays at once. In the rare cases of refusal the matter is taken into court and a

summons is served after a date for the hearing has been fixed.

III.

Civil Procedure.

10. Civil procedure by the Forest Department on behalf of owners of forests subject to its control.— As representatives of injured proprietors Forest Officers may press the civil action which is the corollary of offences committed against Government and communal woods and public institutions. This power is exercised under Section 159 of the Forest Code which authorises them to prosecute for all reparation on account of a forest offence, and Article 148 classifies fire as a forest offence, except in regard to the penalty. They are further authorised to declare themselves civil plaintiffs in all cases of offence against the common law where forest property is affected, under Article 182 of Civil Procedure Code.

There is this distinction between them and other civil plaintiffs: they have not the choice between the civil and criminal courts. To enable them to institute a civil action for indemnity, an offence must have been committed either against the Forest Code or the Penal Code.

Whether the civil prosecution can run concurrently with the criminal is a controversial matter. Formerly, as far as the Forest Administration was concerned, the two charges admitted of separate treatment. The Court of Appeal, by its ruling of 9th May 1879, decided that: "Criminal Courts can take cognizance of the civil plaints only as accessory to the criminal charge; where the criminal charge on which the civil plaint is based is unfounded they have no power to deal with the latter. In the absence of any forest offence Article 171 of the Forest Code does not empower the Forest Department to prosecute the civil charge separately." This ruling is accepted, at least for the time being and by some jurists.

According to this view, when the criminal charge is quashed and the civil plaint alone remains, Forest Officers are no longer in a position to claim civil indemnification before the criminal courts. The owner alone can now have recourse to the Civil Courts.

However, this detraction from the rules up till then admitted as conveying the correct interpretation of Article 171 of the Forest Code has been criticised by commentators and repudiated by several courts.

The latest ruling on the subject, that of the Court of Grenoble of the 2nd May 1901, protests against the restriction which has been imposed on the powers of Forest Officers since 1879, in the following words:—

> "From a civil standpoint the Forest Administration can take action independently and separately of the criminal prosecution should the latter be quashed."

Where an offence has been committed the Forest Service prosecutes before a criminal court, presenting at the same time a claim for damages in consideration of the injury caused.

Should the fire be accidental, several points must be considered:—

(1) Combining action under Articles 182 of the Criminal Procedure Code and 159 of the Forest Code, the Public Prosecutor may press not only for sentence to the prescribed penalties, but also for damages and restitution in favour of either the communal Council or the State.

(2) The Forest Officer joins issue to claim pecuniary reparation and, as a subsidiary point, to press for fine under Article 148 should the Public Prosecutor fail to secure a verdict

(3) Even when the Public Prosecutor has failed to secure conviction and also the Forest Administration has not intervened as a civil party, the accused, though acquitted, may nevertheless be prosecuted by the Forest Department under Article 148 of the Forest Code.

(4) Finally, though the Court does not take the initiative, there is nothing to prevent the Forest Officer from himself taking action conformably with the right conferred by Article 182 of the Criminal Procedure Code to any injured proprietor.

The author of an intentional fire is prosecuted in the Sessions Court under Article 434 of the Penal Code. In such a case no section specially sanctions the Forest Officer being regarded as a civil party to plead for damages in the criminal court; Puton (Inspector General of Forests), however, asserts this authority as existing in this special case in favour of the Forest Administration.

The amount of damages is fixed by the Court, being allotted according to circumstances (Article 198, Forest Code).

The analogy of such damages to compensation for forest offences has been laid down, notably in Articles 45 and 46 of the Forest Code, according to which the purchaser of a coupe in a forest under Government management is liable for all accidental fires in the coupe or within earshot (*à l'ouie de la cognée*), even though caused by others. The provision for payment of damages under Article 202 of the Forest Code, however, is contingent on an actual offence. When no such misdemeanour can be proved it seems preferable to see in section 148 merely a reference to the common law for civil reparation. There is, therefore, no definite relation between the amount of the damages and the fine. The Forest Department has no power to prosecute criminally under Article 458, nevertheless, application is made under that article by Forest Officers for compensation for injury caused, for instance, as a result of a fire originating from embers in a hut or workshop of the coupe purchaser, located under proper authority. Here the Forest Officer constitutes himself a civil party under Article 458, under the presumption of want of caution or negligence on the part of the perpetrator.

The same procedure is followed in the case of fire caused by a railway engine when the Court does not direct prosecution though admitting rashness or negligence.

Neighbouring farmers at times request permission to light fire for the burning of sods or for other purposes, within the prohibited zone. Such permission granted by the forest department, however, does not remove liability to pay damages under Article 458, if it can be shown that every precaution was not taken. The owner of land where such fires have occurred cannot be held liable, as he is *not* mentioned in Article 1384 of the Civil Code, unless he himself has applied for authority to have sods burnt, say by his tenant; in such cases the latter is merely a proxy.

Should the conflagration have resulted from a fire lit more than 200 metres from the forest, a civil claim, based on the offence, may still be cognizable by the criminal court provided that negligence can be formally and clearly proved. Failing proof of negligence there is no criminal offence and a civil court alone has power to adjudicate. On the other hand, the respondent wrongfully charged in a criminal court has power to sue for reparation.

The case should be filed by the Forest Officer within 3 months of drawing up the report and should make not only

a civil claim but also press for a fine under Article 148. The latter point may be withdrawn later if desired.

11. In civil suits Forest Officers appear in consultation only.—Generally speaking, Forest Officers have no *locus standi* when no offence has been committed. The case becomes a purely civil one and they are no longer concerned; at least not in a leading rôle, for almost invariably they are called upon by the owner of the forest in consultation to support the claim by their expert opinion.

12. Civil suits in which the State is concerned.—In civil suits relating to their real estate, the State and communal bodies are in an exactly similar position to private parties. The same laws and the same jurisdiction apply but special formalities regulate the procedure.

When the State wishes to sue a private person a memorandum of the claim is presented to him and after the expiration of one month he is served with a writ (Ministerial Regulation of 3rd July 1834).

This memorandum is specially drawn up by the Forest Department, but it does not interrupt the course of prescription and the only way of safeguarding jeopardised rights in case of urgency is by serving a writ.

The brief is framed by the Forest Department and submitted to the department in charge of State lands which forwards it to the Minister. Immediately a decision has been declared it is referred to the Prefect.

It is this latter officer who is charged with the filing and conduct of suits on account of State lands and the whole procedure is in his name. The active agent is, however, the "director of domains" who can appear in court and assume the functions of a solicitor.

The Attorney to the Republic is counsel for State domains (order of 10th Thermidor, year IV). In important cases, in addition to these two regular assistants, the prefect may call barristers and solicitors in consultation.

13. Civil suits by communal bodies.—The same rules apply when a communal body is the plaintiff, with the following modifications: The Mayor takes the place of the Prefect and he must obtain the consent of the Municipal Council. Communal bodies are exempted from presenting the preliminary memorandum. Before the proceedings begin the brief must be submitted to the Government Solicitor.

14. Civil suits on behalf of public institutions.—Analogous rules govern the conduct of civil suits by public

institutions, but here the administrative committee replaces the Mayor and Municipal Council.

15. Suits by private persons. Legal procedure.— Any prejudicial act must be compensated (Articles 1382 and 1386, Civil Code). There are several ways in which the victim of a fire can obtain reparation for the injury sustained :—

(1) When reluctant to risk the costs of legal proceedings, and if the circumstances of the case bring it within the purview of any article of the Penal Code, the Forest Code or one of the special laws of 1874, 1885 and 1893, he may submit to the Government Solicitor a plaint (Article 63, Criminal Procedure Code) recording the illicit acts and enumerating the witnesses to be cited.

Being satisfied as to the correctness of charge the authorities order an enquiry and take steps to bring the guilty party before a criminal court.

(2) When the evidence is so obvious that condemnation appears certain he should constitute himself a civil party to the suit by a personal application to the Registrar (Articles 66 and 67, Criminal Procedure Code), for then his case will be dealt with summarily, with practically no cost to himself and with the minimum of legal formality. However, when he is himself a witness, he can only become party to the suit after he has undergone examination at a sitting of the court.

(3) The plaint need not necessarily be submitted to the Government Solicitor. When the acts complained of are manifestly illegal the owner of the forest is at liberty to appear as a party to the suit in a criminal court. His summons to the defendant enables the court to take action (C. P. 182) either under Article 148 or Article 458, independently of the Public Prosecutor.

This procedure (taking action as civil party to the suit) has the advantage of being more expeditious and more certain, as well as less costly, than a purely civil suit for the recovery of damages. In case of acquittal, however, it involves payment by the plaintiff of all costs, not only his own but those of the Public Prosecutor, and, in addition, exposes him to a counter-claim for damages on behalf of the defendant. This course, therefore, should be adopted only when the acts complained of are illegal and the evidence uncontrovertible.

(4) When the plaintiff has not joined issue as a civil party to the case and the accused has been found guilty at the instance of the Public Prosecutor, the former, armed with the judgment, need have no hesitation in filing a civil suit.

On the strength of the sentence pronounced he is certain of securing a verdict in his favour.

(5) Even after failure to obtain a conviction by the Public Prosecutor, a private person may still have recourse to a civil court and present a claim for compensation.

Finally, when the facts of the case do not disclose illegal acts or do not seem to warrant action by the Public Prosecutor, the owner may nevertheless file a civil suit (Articles 1382, 1383 and 1384 of the Civil Code).

16. Appraisements. Formalities.—The Procedure Code (Articles 302 to 323) regulates the framing of judicial appraisements.

The experts called in by the court must not only conform to all formalities imposed by law, but must, technical points apart, consult solicitors or counsel and carefully follow instructions. In Appendix H will be found a skeleton report which might readily serve as model for a large number of appraiser's reports. The judicial form and text should be adopted word for word and the signature of the parties obtained in the places indicated. The report should be submitted to the office of the court ordering the appraisement.

Chapter II.—PREVENTIVE AND PRESERVATIVE MEASURES. ENQUIRY.

17. Preventive measures : private forests.—No regulations compel private owners to take special measures, their own interests will drive them to adopt means for the prevention, extinction and restriction of fires.

The precautions, control of conflagrations and inquisitions to assist the course of justice are, of course, the same as for forests subject to the control of the Forest Department. We may restrict ourselves, therefore, to a consideration of the latter, which will include all points that concern private forests as well as certain formalities that apply to them alone.

18. Preventive measures : forests in general. Cause of fires.—In France forest fires only assume large proportions in pine woods or in certain special tracts :—Maures, Esterel and Algeria. All woods, however, are liable to fires, particularly during certain seasons.

Towards the end of winter the natural drying of the soil covering : grass, mosses, lichens, deadwood and fallen leaves, often coincide with a minimum rainfall as well as with the occurrence of violent and continuous winds. As has been

pointed out by M. Borel, the comparative absence of clouds during the early portion of the day further aggravates this condition. The ardent sun of March completes the desiccation of the fallen leaves which since their fall formed a compact sodden layer pressed flat to the ground. Under the action of the sun they now curl up and are raised into a more diffused, aërated stratum. These are most favourable conditions for the outbreak and rapid spread of fires, and it is at this season that they most frequently occur. A glowing match, a smouldering gun wad, a lighted cigarette end, is sufficient to kindle the soil covering. Such a fire can so scorch the undergrowth and even trees as to cause eventual death. The conditions are also critical at the end of summer when the whole of the undergrowth becomes eminently combustible and the shrubs themselves feed the fire, assisting it to a more rapid development. In the South of France and in Algeria the greatest danger occurs during the months from July to September.

At this period night and day patrols must be organised (Circular 684 'old series), the burning of sods and coppice débris in the neighbourhood must be strictly prohibited, and a rigid and minute supervision exercised over charcoal kilns, workshops and the burning of rubbish.

Although mysterious fires have been attributed to lightning, to the fall of aerolites and to fractions of bottles acting as lenses, there can be no doubt that the chief agency is human.

The preventive measures imposed by special laws in the Maures, the Esterel and Algeria have proved their validity and in the latter they have been aimed specially at regulating the use of small open fires. In the Provence, in addition to the last precaution and the exercise of the greatest vigilance, the most effective means of restricting catastrophes have been employed: the compulsory maintenance or a series of open rides or fire-breaks along the confines of each estate.

An extension of this principle is the clearing of brushwood on a belt 4 metres wide along the most frequented roads and path-ways.

The opposition offered by the department *des Landes* to the promulgation of a special law for that part of Gascony is incomprehensible.*

* The Senate at the sitting on 18th May 1895 had voted the urgent necessity for the introduction in the Landes of a law against fires incorporating in part the special regulations applicable in the Maures et Esterel.

Preventive measures similar to those that have proved so efficacious in the "fire zone" would bring about the same excellent results in the Lot-et-Garonne, Gironde and the Landes. If proof is required, the outcome of the measures taken on the initiative of the parish of Onesse-et-Laharie will furnish it. In that parish since 1892, thanks to a Syndicate, the owners of *pignadas* (forest of maritime pine) have succeeded in nipping in the bud the numerous fires (40 in one year) by which they were being ruined before this concerted action was introduced.

In the pine forests of the rest of France, though they do not cover such extensive areas as here, fires still cause far too much damage and protective belts should be established. This has been advocated in Germany by Dr. Kienitz and in France by M M. Broillard, Buffault and Lieutenant-Colonel Marchand. The ground must be cleared of all material capable of producing a high flame, such as heather, juniper, tall grass, dead wood, etc.; the carpet of short grass, mosses and lichens need not be disturbed. Cultivated land affords the best protection: pasture, vineyard, or weeded plants: potatoes, Jerusalem artichokes, onions, etc.

Where the soil is too poor and sterile or the situation is too distant from a market to recommend this resort to agriculture, broad leaved species should be planted such as the oaks (sessile, penduneulate, occidental or Holme oaks), poplar, birch, robinia or mulberry; they form a barrier, possibly not impassable to fire especially when the clearing of undergrowth has been neglected, but still sufficient to retard its progress and enable repressive steps to be taken in time. Ailanthus (A. glandulosa) and the ash-leaved maple have been tried similarly, but owing to undesirable properties are best avoided.

According to M. Buffault the principal object of these firebreaks is not to form a break in the continuity of the forest of sufficient width to arrest the progress of the fire, for in burning *pignadas* the cones burst and their ignited segments as well as various fragments in combustion are sent flying over distances of more than 100 metres. The utility of these lines is rather to serve as a base from which repressive measures and counterfires can be started; their width is therefore a secondary consideration.

In Prussia the Legislature has ruled the punishment of any person who enters a forest carrying a naked flame. The smoking of cigars, cigarettes and uncovered pipes

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constitutes an offence under this decision. In France it might be alleged that Article 148 of the Forest Code gives the same power to prevent smoking, but it is doubtful if the courts would act upon it. In the province of Gironde Article 2 of the prefectorial order of 11th March 1889 prohibits smoking in pine forests; however, as it is not reiterated yearly it is as little known as it is rarely applied; in fact no precedent for action is yet forthcoming.

Less drastic measures than fire-breaks also are adopted by the Forest Department in State forests, including the establishment of permanent observation posts supplied with implements, notice boards, telephonic communication and the clearing of belts along roads. During the critical periods a particularly rigid vigilance is exercised.

Fireproof or incombustible hedges of succulent plants, such as *cacti*, have been recommended. M. Roland-Gosselin has suggested *Opuntia ficus-indica* (Barbery fig) and *Opuntia balearica* as likely to become readily acclimatised, the first in Provence and the second in the South-west.

As regards railways the best protection against live cinders and sparks thrown out by passing engines is by means of thoroughly cleared belts from 10 to 50 metres wide according to local conditions on either side of the permanent-way, **at the expense of the company**. In the department of the Maures et Esterel this is incumbent on railway companies under Article 11 of the law of 19th August 1893. Such belts must be cleaned at least twice in the year or they may be converted into meadow land. Should the railway authorities decline to defray the expenses of this work or to maintain the belts cleared themselves, the best means of convincing them is by drawing up a formal authenticated statement in proper form in every case of fire caused by their locomotives. That such precautions are not universal is due to the apathy of the owners injured. This reluctance to force the hands of powerful companies appears to be general as is evidenced by the confession of M. Desjobert in an article which, though couched in humourous vein, nevertheless presents a serious foundation and is full of sound commonsense. He admits that in spite of the urgent advice of one of his collaborators, he feared to prefer his claim "convinced that he would not succeed in proving the origin of the fires and that should he prosecute the railway companies he would not obtain a favourable verdict. This was, moreover, the opinion expressed by the two lawyers he consulted."

However, on one occasion he ventured to draw up an occurrence report and the company paid up at once. Elsewhere, in certain provinces where the law meets with less respect, where the education of managers and overseers is not up to the standard demanded by their duties, oftimes of a delicate nature, and where the population looks upon forests as being somewhat of a nuisance, legal steps are avoided through fear of difficulties and even the loss of the suit, badly prepared and supported neither by public opinion nor precedent. Even here, however, forest proprietors can overcome such obstacles by firmly declining all compromise, by training their foresters and giving them definite and clear instructions regarding their responsibilities.

Not only will they succeed in extracting indemnity without serious difficulty, but railway companies will not be slow to avoid the repetitions of costly accidents by taking the requisite measures of prevention. Such individual action, therefore, will achieve the object aimed at in the resolution of the general meeting of the French Asssociation of Agriculturists, held on the 12th March 1901: "precautions incumbent on railway companies to prevent the occurrence of forest fires, specially in pine woods, along permanent ways, resulting from live coals, etc., thrown by locomotives."

19. Extinction of fires: forest controlled by the Forest Department.—On receipt of telegraphic intimation from his Guard (Standing Order of 19th July 1882), or information from other sources, of the occurrence of a fire, the Range Officer must proceed without delay to the locality and notify his divisional officer (order of 23rd March 1821) and the Conservator (Circular of 19th August 1884) by means of brief memos.

In a serious case he informs the Director of Forests by telegram (Standing Order of 19th July 1882, and Circular of 19th August 1884), and customarily the Conservator as well as the Prefect or Sub-Prefect. He demands the assistance of fuel and other right-holders; a verbal requisition is considered equivalent to a formal summon.

It is the Ranger who directs the measures for controlling and extinguishing the fire; but in this respect he is not so well supported by law as the Police or Municipal bodies.

The simplest method of extinguishing a fire is to beat the burning grass and bushes with green leafy branches or with wands. In the absence of roadways or cleared lines

an efficient fire-break can be prepared by denuding the soil with spades and rakes.

In resinous forests fires frequently travel faster than the workers can. If the organiser of the measures of repression finds himself powerless to stop the progress, either by following up or working against the fire, he must calculate the rapidity of its advance and estimate the area that he must be content to sacrifice, giving due consideration to the strength of the wind, the quantity of combustible matter in the locality, the number of men at his disposal, etc.; then, retreating sufficiently to leeward of the flames, he himself sets fire to a belt of forest small enough to remain well under control. He should take advantage of tracks, rides and glades to diminish the area sacrificed and to increase the effectiveness of his operation.

This 'counterfire' creates a blank—the conflagration arriving at the belt thus cleared goes out for want of fuel. This drastic measure is authorised by the report of the commission convoked to enquire into the projected law of 19th August 1893, which also indicates the conditions under which it may be resorted to. Theoretically, counterfiring should only be adopted in the regions of the Maures, Esterel and Algeria. Actually, when circumstances demand its application, it will be endorsed everywhere. Nevertheless, Forest Officers will be well advised to exercise great caution and to support themselves with the orders or at least the formal consent of the Mayor or the Police.

Depositions.

20. Occurrence Reports.—Forests controlled by the Forest Administration.—After the extinction of the fire the Ranger must proceed with the recording of depositions and drawing out of an occurrence report; the detection of the perpetrator; the estimation of the damage done. If he has not yet submitted his memo. to the Conservator, he will now draft it as well as an occurrence report and a general statement. In cases of minor importance, or when the Ranger has not been able to arrive on the spot in time, it is the Guard who frames the occurrence report. At all events, the report is submitted direct to the court of enquiry by its author, even before registration, in order to avoid any delay. According to Article 29 of the Criminal Procedure Code, the report should be sent to the Divisional Officer, but the departure advocated above

hastens the receipt of information. A further advantage is that in case of subsequent prosecution the authorities are in possession of the original report. It is submitted to the head of the department who consults the Public Prosecutor as to the further steps to be taken and communicates the reply together with the occurrence report to the Conservator (Circular 146, old series and orders of 23rd March 1821). The proposals for compromise, if any, and the Ranger's report with his estimate of damage is sent at the same time (Circular of 19th August 1884).* When the fire has been caused by a railway engine the joint report, as specified in Circular 572, is added to these; if it has not yet been drafted its preparation and subsequent despatch is intimated.

If any persons summoned to give their assistance have refused to comply, a special report against them must be submitted (Orders of 23rd March 1821).

Special mention should be made in the reports of such as show special zeal and whose assistance has been specially helpful in view of possible reward (Circular 416)..

Certain Conservators instructed their subordinates to inform the Prefect or his deputy by ordinary letter, giving the leading facts detailed in the special report; this procedure, however, has fallen into disuse.

Should the injury necessitate the cutting back of the growing stock in the area burnt over, an estimate of the cost of this operation should accompany the report. The Forest Department requests the parish authorities to undertake the work as early as possible, at the expense of the parish funds. Should they refuse the matter is referred to the Prefect for settlement.

After the sum fixed for composition, or the fine imposed by the court in case of prosecution, has been paid by the incendiarist, there is frequently a certain amount of delay before the treasurer of the parish can receive the amounts payable to the workmen engaged on cutting back operations. Occasional delays may be expected as the sums are received in the collectorship in which the payee resides, or else at the head-quarters of the department if his residence is in another department, and time for effecting transfers must be allowed.

21. Quest of the author of the fire. Forests in general.—It is highly important that the cause of the fire

* Some examples of such reports will be found in the Appendix.

should be clearly proved in order to fix responsibility. The origin may be due to unwatched burning of sods or to too many furnaces and in too close proximity to the margin of the wood, want of caution by a smoker or sportsman, neglect on the part of a wood cutter or charcoal burner, sparks from a railway engine, fire balloon, malicious incendiarism, etc. Investigation properly directed, following natural clues and taking note of the direction of the wind, paths, traces of passage, etc., will more often than not prove successful. Such advice may seem superfluous if not derogatory, the searching out of the perpetrator of a conflagration being an obvious duty. Unfortunately, experience points to the desirability of laying stress on this point. In certain regions the formula "author unknown"* is generally forthcoming. A convenient method but one not compatible with the truth in all cases and not reflecting credit on the Forest Officers concerned. This brief negation is easy and definite ; detailed enquiry is dispensed with and delicate inquisitions and deductions are superfluous ; on the other hand, in relation to State and Communal forests, it does not harmonise with the energy and zeal to which the Forest Department can claim just title.

Almost invariably rapid initiative and skilful enquiry, energetically followed to its conclusion, will result in unmasking a culprit whom no facts appeared to inculpate at the start.

The point where the fire originated will indicate the line along which enquiry must be followed. Fires starting remote from roads or paths raise suspicion of intention and malice; such suspicion receives further support if the fire has started nearly simultaneously at several separate points. A careful inspection of these starting points occasionally reveals a clue of identity : articles belonging to the incendiarist, or at least traces of the preparation of a hearth.

Statements of witnesses, of persons working in the neighbourhood or who passed through the vicinity, frequently afford valuable indications, more especially if taken down immediately, before the lapse of time or external influences have affected their memory or suggested excessive discretion. In short, success depends on the perspicacity and the energy of the enquirer. It is intolerable that the owners of forests should suffer through the apathy or incompetence of

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* Such a *non possumus* attitude is not unknown in India though, it must be admitted, with more justification under existing circumstances.—*Trans. note.*

their managers in this matter; failure is doubly to be regretted for it will repeat itself in the future.

Impunity encourages the recurrence of fires, whereas repression checks negligence and deters from crime. What finer example of the power of indefatigable devotion, of persevering intelligence, can be put forward than the triumph of the patriot Charles de Ribbe, the instigator of the law which has saved the region of the Maures et Esterel? Though such great results are the prerogative of exceptional men, nevertheless, in our restricted spheres, we can and must each individually bring all our best efforts to bear to safeguard the interests confided to our loyalty.*

* Some examples will be found in the Appendix; they are by no means imaginary, being extracted from administration reports.

PART II.

GENERAL PRINCIPLES OF ESTIMATIONS. RATES. VALUES OF A FOREST AT ITS DIFFERENT AGES.

CHAPTER I.—GENERAL PRINCIPLES OF ESTIMATIONS.

22. Definition or object of the estimation of injury..—The object of the calculation of the indemnity payable on account of injury is to replace the owner in the *status quo ante*, that is to say, in a pecuniary condition equivalent to that attained by his management prior to the injury. Such is the guiding rule of all appraisements. In sylviculture this object can be secured more or less rapidly as the reconstitution is effected at once or is spread over several rotations. Economists of note interpret the above definition in its strictest sense and insist that the former conditions must be re-established as soon as possible, even though greater expense is entailed.

23. Errors or arbitrary valuations of most appraisers.—All estimates of this description are of a subtle nature. It is probably in the case of woods injured by fire that the greatest difficulty is met with and that the governing principles are least studied.

Excepting among a few specialists the general ignorance of forest economics is so profound that most insurance companies lay down the same conditions for forest property as for buildings; and the public accepts them! Speaking at a conference on this subject held in Belgium, one of their officers, M. Herbrand, stated that in assurance against fire the least known and most neglected branch was that relating to forests.

Decrees are founded on the conclusions of valuers; but their surveys are often incomplete, conducted without method and in an arbitrary manner and, consequently, may be unjust. Further, policies guarantee only the material loss, the property actually destroyed, deduction being made for the value of what is saved or may still be put to use: salvage. Now, except under extraordinary circumstances, the standing

stock is not consumed even though so scorched that it may subsequently die; consequently, the letter of the contract appears to free the Assurance Companies from any payment. A suit must then be filed to secure a ruling that the indemnity which the insurers expect in return for their premiums extends to the reparation of all injury caused.

In Germany during the past eight or nine years much has been written on this subject. Experts have endeavoured to frame rational rules fair to both parties. Now-a-days, reliable assurance societies accept risk of disorganisation of working and of loss of reproductive power of root stocks. This is a step in the right direction, but the systems in vogue are still far from satisfactory.

The calculations of the injury caused to a forest may be based on two principles:—

(1) To discount the sale value of the coupe from the date of the fire up to the period of exploitation. This is the forester's method and the only equitable one.

(2) To reimburse the cost of planting with interest up to the date of the fire together with interest on the soil value. This system, adopted by two of the most important German Assurance Societies, omits all recognition of skill, vigilance on the part of the owner, results of good management, well executed markings, judicious selections of periods of exploitation. Such facts, however, though of a moral nature and somewhat intangible, nevertheless exercise a very definite effect and result in marked surplusage. By virtue of good management one forest will produce a greater yield than another not so well supervised or under less skilful direction. The first method, that of foresters, does allow for this as it is based upon the length of the rotation and the yield in material and revenue. The second, adopted by assurance companies, draws no distinction between neglected forests and those properly managed, between intensive and reckless exploitation, or between spinneys and large woods, the working of which is seriously disturbed by a fire. Here, the initial expenditure and the soil alone are taken into account, consequently, the rate is arbitrarily selected and does not bear a true relation to the working of the forest, except by chance. It will be readily seen that this system is very vague and incomplete; it suggests a preparatory phase of groping; those concerned, little conversant with the subject, do not seem able to reach the truth, and rudimentary beginnings have not yet made way for precise scientific methods. That this is so is

demonstrated by the constant modifications that companies find themselves compelled to introduce in their tables.

The figures given in Section 110 will expose the errors inseparable from such indecision.

24. Disorganisation of tissues. Physiological estimations.—Certain mysterious vital processes, transcending human knowledge, increase and excuse indecision in matters concerning forest fires. Vegetation depends on many phenomena, such as temperature, humidity, meteorological changes, etc., the influence of which we can so little gauge, that the most erudite of botanists would hesitate to guarantee a healthy plant; the greater reason therefore to theorise with all caution when plants subjected to ill-treatment are in question.

With the exception of pines saturated with resin standing in a dried-up underwood in excessively hot climates, trees cannot burn.* Nevertheless, as described by Muel, the harm caused to the growing stock is very great. The internal layers of the bark are disorganised; the essential functions of the cambium are suspended or at least much restricted; the circulation of sap and even the vitality of the whole plant are destroyed or very seriously jeopardised. The weaker seedlings and those more seriously affected become etiolated and soon perish; the others throw out a few leaves for a year or two, but generally end by dying out as well. At the base of a certain number of saplings the plastic substances accumulated abundantly in the rootstock during the winter, put forth feeble shoots which conceal the evil without curing it however; this re-growth by its show of green will at first cause the illusion of health, but, checked in its development by the dead stems it surrounds, it will remain stunted; better to cut short this feeble attempt, unproductive of any good to the proprietor. More often it will totally disappear of itself. A delayed felling will yield only wood that has lost all good qualities; the enfeebled rootstocks will fail to coppice and replanting will become imperative. From the moment of the fire there is but one remedy: early cutting-back.

An ocular estimate of the damage, whether in high forest or in regard to standards over coppice, is apt to prove deceptive. Even the trees most injured present apparently unimpaired crowns; where branches grow very low the

* Presumably this is meant to apply to France (including Algeria) only, otherwise we must differ from the author on this point.—*Trans. note.*

extreme branchlets alone are scorched. This greenery, however, is misleading; death is certain to ensue before long. The decomposition of the cambium will arrest the descent of the sap. As soon as the young shoots have consumed the nutriment stored in the roots they will perish for want of further alimentation.

With a little practice one can appreciate the degree of injury by an examination of the bark on the side most exposed to the flames. When the interior layers near the wood do not present a natural appearance and are stained a more or less dark brown, especially if these signs appear over a considerable extent of the circumference, there can be no doubt of the loss of the tree at an early date.

When circumstances preclude a definite diagnosis by these means, the tissues most mortified must be analysed. The microscope and chemical reaction supplement the visual test and afford a valuable complement.

The biological phenomena of ligneous growth, more especially during the critical periods, are apparently so capricious as to defy prescience. So many external causes, so many connected or diverging forces beyond our control, enter into play, that our remedial measures, even where a few individuals only are concerned, are excessively circumscribed; where a whole forest is in question our initiative practically disappears.

We should at least be in a position to judge of the situation. The only criterion of the damage actually caused by a fire is the appearance of the stems after the next active period of sap circulation, or better still after the second vegetative phase. Consequently, theoretically speaking, in case of doubt, we should postpone the estimation of the injury till the next one or two seasons and judge of it according as the foliation is abundant or defective and as the new shoots are vigorous or weak. Practically, however, such delays are highly dangerous and to be deprecated.

From the cultural point of view it is far better to decide at once to cut back. If the growing-stock has not been absolutely stricken to death, at least it must have suffered to some extent by retardation of growth, and the error of a premature felling at least will not incur the loss of a full normal crop of leaves.

If, on the other hand, the crop has actually been damaged past recovery and through excess of caution it is not cut back, during this period of temporisation the root stocks

will lose their stored alimentary materials and will then die of exhaustion; the delayed cutting will no longer be efficacious and artificial regeneration will become necessary. Prudence, therefore, will dictate the immediate cutting back of a growing-stock run through by fire, even though to all appearances but little injured. M. Borel goes further and lays it down as a necessary measure. The increment of the trees is arrested for a long period, whereas the root stocks are generally unaffected and ready to form a new growing-stock.

M. Borel, an expert forester of Geneva, carried out detailed experiments regarding the number and volume of stems in certain compartments burnt over when 23 to 24 years old; the visible traces of the fire were so insignificant that both proprietors and wood-cutters had deemed cutting-back unnecessary. Measurements taken at 33 to 34 years demonstrated that there had been no total increment during the decade, the individual increment had but compensated the loss in volume by diminution in number.

The gross yield up to the date of the fire, therefore, could have been realised ten years earlier had the felling been conducted immediately after the accident. Moreover, the normal increment of the re-growth for ten years would have been secured. In Section 118 will be found an estimate of the loss resulting from this technical mistake.

The valuation of damage by fire is complicated by many other circumstances. A similar fire will cause greater injury on dry soils and on superficially calcareous soils than on wet, deep or clayey ones. Again, if the fire passes rapidly it will have affected the wood to a lesser extent than if it had dwelt on the same spot for an appreciable time, though the external appearances may not be distinguishable in the two cases.

It often happens that grass and dead leaves blaze up and blacken the undergrowth without raising its temperature sufficiently to injure its vegetative forces. Plants with a thick rhytidome naturally show greater resistance than thin-barked ones.

Beech and hornbeam are extremely sensitive to heat when growing mixed with adult oak (deciduous), the former sometimes are killed out though the latter may be unaffected. Similarly, where no dense undergrowth has served to increase the heat, it is by no means exceptional to find a white fresh cambium, redolent with sap, under the thick cuirass of an old pine exteriorly scorched and blackened.

When making the plan of an area burnt, the portions severely affected should be carefully distinguished from those through which the flames have simply passed without causing injury to the trees.

The difficulty of correct valuation is increased when coppice is under consideration and fresh coppice shoots have been injured.

The classification of root-stocks into killed and uninjured immediately after the occurrence of a fire is a most difficult, not to say impossible task. Some will be unquestionably charred and useless and others as undoubtedly safe and healthy, but the greater number will have undergone a partial alteration the degree of which can only be estimated by the future appearance of the re-growth.

Under such circumstances a nice feeling for equity and prudence will recommend the postponement of the final report to the end of the next period of active vegetation. If, however, circumstances or the parties interested will not allow such a delay, deduction must be drawn by analogy from known physiological facts, from observations under similar conditions of species, soil and severity of the fire.

Beech, which produces few and weak shoots, suffers more than hornbeam, which again offers less resistance than oak.

Nevertheless, an expert, however good an arboriculturist he may be, would be liable to inaccurate conclusions, were he unacquainted with the locality. The same species have different qualities in varying climates; in the Pyrennees, the favourite habitat of the species, beech poles, corroded nearly all round by successive fires, continue to thrive, whereas, almost anywhere else a single one of these mutilations would have ensured their death.

25. Depreciation of growing-stock. Cultural considerations.—Fire causes depreciation of the growing-stock in several different ways.

Cost of cutting back.

Up to the age of 12 years cutting back will yield no marketable produce; it entails expenditure however. When cutting-back becomes obligatory its cost must be added to the amount of the indemnity from which, on the other hand, the value of the salvage, if saleable, must be deducted.

Reduced value of premature felling.

When the coupe comes under the axe at the date fixed by the working-plan, the area cut back will not have

attained the prescribed age; being younger the material will fetch a low price.

The damage caused, therefore, is the difference between the money yield of the coppice forest at the normal exploitable age of the rotation and that of the younger crop to be felled in its place. The loss, however, being experienced only after the lapse of some time, must be discounted for the number of years to run till the prescribed date of the final felling.

Deficient girth and height of standards due to premature cutting of coppice under standard.

This subject is dealt with at length in Section 81.

Season of cutting back unfavourable for the production of coppice.

If the time of year is unfavourable for the production of coppice-shoots, for instance in summer after the rise of the sap has already been lost, half or a full foliation may be added to the value of the coppice. M. Bartet has shown the influence of the time of year on the production of coppice; a fact which, though previously accepted, had not been demonstrated by exact methods. His experiments in the coppice-woods of Lorraine accord with those carried out in Bavaria by R. Hartig. Shoots resulting from fellings in June and July have not time to ripen and are liable to be killed off by the early autumn frosts. Root-stocks cut back in the first three weeks of August generally remain unproductive till the next year, or if any shoots are put forth they are excessively weak. Two-years-old shoots from root-stocks cut back during the last four or the first four months of the year are as large as those resulting from felling in the previous summer. Therefore, fellings during the unfavourable season—June to August—result in the loss of a year's increment.

Inferiority of artificially-produced plants as compared with coppice-shoots or natural seedlings.

Where the fire has destroyed the coppice-shoots or seedlings so as to necessitate artificial reproduction, not only the cost of the latter operation but also compensation for the inferior vitality of artificially-raised plants compared with naturally-grown shoots or seedlings must be added to the indemnity. The loss here considered results in three ways:—Fewer poles with a reduced diameter, which means loss in volume—a yield of a less remunerative class (small

charcoal instead of billets or fuel instead of pit props)—poor quality of standards owing to weakness of the seedlings.

M. F. Cardot estimates that this depreciation often amounts to half the value of the wood. Calculations on this point are detailed in Appendix D, so no further mention of the method need find place here.

The perpetrator of the fire cannot object to this detriment being taken into account on the ground that new species giving a better and more valuable yield than the ones destroyed can be introduced. Firstly, if the latter were already those most in demand in the region his contention has of course no foundation. Secondly, even admitting that there was an admixture of less valuable growth, no one has a right to force a change in working on the proprietor even if it be to his advantage. Finally, it is easy to advance specious arguments regarding the high returns produced, for instance, by conifers introduced in place of broad-leaved species and even to support them by plausible figures, but the peculiar contingencies of fir and pine forests must not be overlooked; from the difficulties with plantations to the attacks of insects, the danger from cyclones and the incessant care required for their good management, etc. M. Henry, the learned entomologist of Nancy, "truly hesitates to recommend the introduction of conifers in view of the ever increasing number of their enemies, which bring about either death or defective vegetation." One cannot refrain from sharing these apprehensions in face of the disasters of 1892-95, which laid waste a portion of the Champagne, and of the startling suddenness with which in 1902 an attack of *Pissodes* devastated superb pole-forests in Lorraine as well as in Burgundy.

The unharrassed owner of a coppice-wood yielding 3 or 4 per cent without the least trouble may well decline on the score of rashness any attempt at conversion to working for pit-props or telegraph-posts. He may perhaps obtain an extra 1 to 2 per cent, but at the cost of a thousand and one anxieties and even at the risk of ruin. The mirage of a hypothetical gain would be too highly purchased.

Weeds.

As with agricultural crops so in the forest, the species we desire to cultivate come into competition with inferior and useless ones. In all varieties of climates and on all descriptions of soils the struggle for existence goes on,

though not invariably in the same manner, subject to the same delays or with the same intensity. The surroundings, geological formation, species, canopy, aspect, density, etc., all exert their influence. In order to trace the evolution of a forest each portion would have to be separately dealt with and the vegetative phenomena of each minutely studied. To give an instance, the following description of a coppice-wood on successive aspects overlying Oolithic strata in the Haute-Marne is extracted from observations recorded by M. Tézenas.

The working gives preference to oak, beech and hornbeam. Hazel, Dogwood (*Cornus*), privet and especially brambles and thorns are very abundant and encroach on all sides. These yield small charcoal of poor quality and difficult to sell, or else faggot wood the exploitation of which often proves onerous.

These weeds reproduce with extreme facility and in great abundance and their growth during the first few years is very rapid. No sooner have they been cut than they sprout again and the younger they are cut the more numerous are the shoots. With their rapid early growth they immediately overshadow the less fertile, slower and more delicate superior species; the latter, dominated from the start, grow badly, languish and in part disappear, smothered under the shade.

From the 18th to the 22nd year, according to soil, the weeds begin to slack off in their growth; their canopy becomes less dense; the thicket thins and opens out. The hard-woods that have survived can now hold their own; being longer lived and retaining till a later age the power of growth, they now soon overtop the weeds and from this moment achieve a satisfactory development.

Should the coppice be cut over before the definite victory of the better species, the weeds on the point of death are given a new lease of life and their re-growth springs up denser than ever, whereas the choicer elements, still suffering from the effects of previous suppression, are placed in a most unfavourable condition. Many root-stocks die, exhausted; the remainder produce etiolated and sickly shoots which, unable to support the struggle, disappear even before the end of the rotation.

On the other hand, if the growing-stock can be left undisturbed, from the age of 20 to 22 years the oak, beech and hornbeam are able to take advantage of the slackening of the weed-growth; their heads penetrate through the

thinned canopy, spring up and themselves become the dominating crop; their crowns reaching the full light develop, expand and overshadow the inferior species, which, having arrived at the period of their existence, die off—at least in part. It may be said that now two stories are formed, the one suppressed and dying, the other dominant with its crowns free and untrammelled and rapidly developing. A few years more and the thorns, hazels, etc., disappear. The copse cleans itself and prepares for the eventual exploitation an unencumbered cutting-area and free circulation throughout a crop of high-priced wood.

Under other conditions of soil and climate the succession of these phases in the life of a growing-stock may vary to a certain extent, but the main outline is constant: the harmful or useless shrubs obtain the upper hand during youth but in the long run the valuable species are victorious. Numerous precedents demonstrate that 3 shortened rotations have proved sufficient to bring about the ruin of good simple-coppice woods and to reduce their yield by one half. In certain forests the wood-cutters demand 50 francs per hectare (16 shillings an acre) for weeding before setting to work on paying felling; the latter yields now only 90 francs worth of small charcoal without any billets, giving a net profit of 90—50=40 francs (12*s*. 10*d*. per acre), whereas formerly it amounted to 200 francs (64*s*. per acre).

The same deterioration is found in the lower storey in stored-coppice, though, owing to the standards, the loss is smaller. The standards themselves, however, suffer severely through the loss in height-growth and the want of good standards in the next rotation as a result of the inferior advance-growth.

Now, a fire brings about this degradation by causing two premature fellings, one immediately after its occurrence and another at the date fixed by the Working Plan. This repeated invasion of cumbering saplings entails loss. This is calculated by the area they occupy in the forest burnt over, or, if they are no longer recognisable, in similar areas, under-aged or badly managed, and the yield for an equivalent area is deducted from that of the coppice under consideration.

It is improbable that no woods subjected to improper treatment can be found in the vicinity for comparison. However, in case there are none such, the proportion of area under weeds in adjacent well-tended coppice areas of an

approximately equal age to that burnt, should be noted, and in order to compensate the adverse conditions set up, this area under weeds will be reasonably increased, but not more than doubled, and considered as unproductive; for indeed the value of the produce will barely cover the cost of exploitation, even if it must not be reckoned as a set back owing to its discouragement of purchasers and workmen.

26. Conventional indemnity.—Further points needing consideration are the questions of *personal convenience, vexation, derangement of sales, discontinuity, æsthetical damage and disfigurement* in woods managed as parks or pleasure grounds. Such injuries, though they cannot be readily formulated, are none the less real and may frequently entail the loss of sums exceeding the capital invested. Nevertheless, we must discriminate. When the individual author of a fire is known he must be compelled to make good this damage. An intelligent and honest estimation alone can establish the pecuniary valuation, for, in the absence of a commercial standard it must be a *conventional* one, and it is under this title that it is recognised by economists. Certainly an estimate of such moral value should be a moderate one.

If, on the other hand, direct responsibility cannot be proved and a claim is being preferred before an Assurance Company, all such questions of sentiment must be abandoned and the estimate of loss must be based entirely on material losses, the only ones guaranteed in the absence of special clauses in the policy.

Certain other losses must also appear as accessories though they can be accurately stated. For instance, *expenses incurred on extinguishing the fire:* tools, labour, forest sacrificed in counterfiring, etc. Under Article 198 of the Forest Code, the Court is empowered to fix their aggregate according to circumstances. And similarly with unforeseen sundry expenses: enquiries, valuations, termination of current contracts, forfeitures (Section 121 *infra*).

27. Hypothetical points to be reduced to a minimum.—Except where estimations by observation are indispensable mathematical deductions alone to be accepted. Only cultural facts supported by authority to be admitted. Basis of prices.

In forestry estimates cannot attain to the absolute precision of purely speculative calculations since they must perforce be founded on valuation by observation and on the probabilities of yield, themselves conditions subjected to the caprice

of nature. Certain methods, however, allow the reduction of hypothesis to a minimum; these must be given preference.

After the indispensable data have been obtained in the forest, all deductions must be drawn mathematically. The only exception is where certain *conventional* items are concerned in which an æsthetic or personal element appears. Vague valuations must be discarded. Arbitrary settlement leaves room for doubts and delivers the appraisers to the mercy of a contentious opponent who proposes another figure.

Where cultural operations are in question only universally accepted laws and facts should be admitted, and it is as well to support even these by reference to undisputed authorities. Much bickering will be forestalled and argumentation brought to an early close by avoiding all deviation from principles laid down by the masters of forest science.

The standard of prices to be adopted in calculating an actual injury must be actual prices, but here a definition is necessary. These values vary incessantly; the price-curves for a single region show considerable divergencies and are marked by sudden and frequent rises and falls. One cannot tell that one is not just then at a critical and abnormal period, which is only revealed by subsequent events. For this reason actual prices must be taken to mean the averages of the five to ten preceding years. In any case, conjectures on future variations, being unsupported by any reliable evidence, are inadmissible.

28. Conventions adopted in this work.—In order to simplify calculations areas, whether of land or forest, are invariably reduced to the unity of one hectare.* Except with reference to forests treated under the Selection System all growing-stocks are considered to be even-aged.

The prices quoted are *net*, in order to avoid the complication of the formulas by any reference to cost of felling, conversion and transport.

The calculation tables known as *Cotta's* are usually employed, as they greatly simplify the calculations. These tables, however, do not carry one beyond 5 per cent, whereas most coppice-woods, as well as standards or trees in high forest, double their value in less than ten years at a certain period of their youth, just at the time they pass from the class of charcoal or faggot-wood to that of billet-wood and timber. At that critical period the material, and sometimes even the money capital, is returning 6 per cent and may reach 10 per

* See Translator's note, pages i and ii.

cent. Therefore, it may be useful to refer to these rates and the tables have been amplified accordingly. The expanded tables will be found as appendices indicated by the numbers usually employed for them in France as well as in Germany.

II.

Rate of Interest.

1.—Systems proposed for determination of rate.

29. Diversity of theories on rate of interest.—The rate of interest is the relation the mean annual net revenue bears to the capital which produces it.

In periodical exploitations it becomes a kind of average of all other rates through which the value of the stock passes from the beginning. It is the primordial element and one of the chief factors in all valuations.

The determination of the correct rate of interest is one of the most difficult problems economists have had to face.

A single volume would not suffice to describe and analyse the various doctrines and theories on the subject, some entirely erroneous, often confused, all disagreeing, complicated and vague definitions being the only feature common to all. This diversity is partly responsible for the nebulous and unsound speculations regarding forest property; the resulting vagueness has caused much dissension among experts.

Every theory advanced has been controverted and no writer on the subject has succeeded in getting his ideas finally accepted. The principles may be summarised as follows:

30. There are two kinds of valuations: relative and positive.—One of two descriptions of valuation is usually adopted: the one positive—that of real-estate agents; and the other relative or dependent on the revenue. The first aims at the current market-value from a general point of view, without consideration of the object. This is adopted to fix the rate either directly when the rotation contemplates a single felling only, or indirectly where the result of intermediate fellings must be added to the final yield.

31. The relative valuation should be employed only for the calculation of certain definite values.—The second valuation calculates the rate for properties only with the definite aim of production for the benefit of the owner, such as an investment at so much per cent. It should be utilised only within restricted and well-defined limits, for

instance in the determination of capital values, as far as the owner is concerned, of a forest for which all other data are known. It also gives the value of crops realised, which may be required in view of an indemnity. This is precisely our case.

This system is based on mathematics and it has been often erroneously held that its application could be extended, notably to the valuation of the soil. Believing it to be of universal application many high-sounding titles have been applied to it, and it has been termed the *scientific system* as opposed to that of timber merchants, which is deemed empiric. As a matter of fact, it varies in the same forest with the age of the growing-stock and the method of exploitation. Requiring a fine discrimination in its use, the greatest circumspection should be shown in applying it and, except under the special circumstances indicated, it should be avoided in judicial valuations.

It is necessary to insist upon these points, concerning which the vaguest notions exist. The great importance of determining the correct rate is amply demonstrated by the examples given later, which reveal the errors entailed by an arbitrary selection.

32. The precognition of the revenue cannot replace that of the rate:—In order to avoid the trouble of surmounting the difficulty, which actually does exist, it has frequently been denied or ignored or circumvented. In this way, it has been attempted to accept a single rate for all forests in one region, affirming that the knowledge of the revenue is sufficiently precise to serve as a basis for the determination of the capital value. The example given in Section 42 will show how false is this dictum and, indeed, it overlooks three essential rules of forest economy:

1. The revenue being rarely equal to the money-possibility of the property it follows that the revenue test is not perfectly accurate. It is true that a scrutiny of the marking-register will reveal whether the growing-stock has been increased or decreased in value, but the exact proportion cannot be ascertained. M. Hüffel warns us of the danger of inferring the value of a forest property from its revenue. In the case of forests there is rarely, if ever, a rental.

The method by annuity, difficult to calculate, leads to false solutions, as M. Galmiche has demonstrated. "The annual yield per hectare is a mean which is only attained, and that approximately, by the felling at the mean age, for instance at 15 years in a forest under a 30 years' rotation; it

should be reduced when applied to the valuation of a forest under a shorter rotation." This system infers that the annual increment is a constant figure, which is never the case.

When the forest is not normally constituted it must be split up into even-aged compartments, and the results of the calculation can only be applied to the class of the mean age. Thus, fictitious volumes are attributed to growing-stocks and a constant annual increment in value and volume is postulated. Almost invariably a double error is thus entailed.

33. Inaccuracy of analysis of sales of forests.— 2. Comparison between forest properties, even apparently similar, is extremely difficult in principle. In practice it is well nigh impossible because transactions in such estates are rare and then the details are not divulged, at least with any regard to accuracy. The relation between the price, the merchandise sold, and the condition of the crop, is not known. The latter may have been so exhausted prior to the transfer that it will not be capable of repeating the same yield in the next rotation. Moreover, forest property is *sui generis*; the revenue' is incorporated for a more or less lengthy period in the capital itself, and the distinction between the two financial elements is a question of great complexity.

The prices vary so greatly according to the method of utilisation; the aim and object of management; the sylvicultural system of treatment and manner of carrying it out; the length of rotation, etc.; that all practical comparison is out of the question. M. Hüffel has drawn attention to this fact in the following words:—"Endeavour has been made to rely on the data of sales of other forests in the same locality, but this analogy is without foundation and accurate results are not to be looked for from this source." Granted that the data of the sale are truthfully stated, that the management, sylvicultural system, exploitability, are identical, it still remains necessary, for the estimation of the crop or coupe to be compared, to carry out a tedious enumeration and a detailed enquiry into the soil valuation, the saleable produce and the determination of the periodical revenue. But, except in the case of simple coppice, no two crops are identical; the number of trees may vary infinitely. It will, therefore, be imperative to analyse in detail the very forest of which it is desired to obtain a more scientific valuation and to begin again for it what has already been achieved for the first type: that is to say, enumerate its products and value its soil in accordance with the current market-price of

neighbouring lands to determine the rate of interest. This again introduced into the calculation will yield precisely the same result as the course commonly adopted by timber merchants. This elaborate procedure will indeed furnish an accurate estimation, but the whole of the first portion of the process will have been superfluous. Consideration of the essential steps will indicate by elimination that the single, simple and exact method is by absolute valuation.

34. Fluctuation of rate.—The rate varies with age in the same forest.—3. Though the soil-value and the composition of the growing-stock remain constant, yet the rate of interest fluctuates. At an early age the value of the soil is greater than that of the growing-stock and the rate is low. Thereafter, the latter rises gradually. The soil value being immutable, a period arrives when it is rendered practically negligible by the constantly increasing value of the stock. The rotation, however, is also lengthening and the rate, after reaching a maximum, gradually decreases. The climax necessarily coincides with the moment when the soil-value ceases sensibly to influence the law of formation of interest.

When the stock supplies two special kinds of merchantable products there may be two maxima, but the phases are none the less developed in the same fashion and order and the several values exert their reciprocal influence in an analogous manner.

The rate remains at its maximum for a period and then falls as the exploitable age increases, since, granted a judicious felling-age, the capital increases normally far more rapidly than the interest. This fall of the rate is universally admitted, and should proof be desired, any figures taken as example will furnish it.

Example.—Coppice on an area the soil-value of which is 500 francs.

Ages.	Value of Growing-stock.	Corresponding rate of interest.
		Per cent.
20 years.	400 francs.	2·96
25 „	600 „	3·18
30 „	925 „	3·55
35 „	1,200 „	3·56
40 „	1,450 „	3·46

It is only when the rotation has been so improperly regulated as to bring woods under felling long before they have attained the maximum mean annual increment that the value increases sufficiently rapidly to prevent a fall in interest. Arguments based on such premises cannot be discussed.

A variation in the system of conversion, or a change of market and of prices, may entail a corresponding alteration in dimensions, which is equivalent to a change in age of exploitation; for a well-advised proprietor will modify the management of his forest accordingly. Such special conditions do not affect the principle. The Tharand Forest Academy, to the opinions of which the practical results attained lend great weight, declines to treat the rotation as immutable. Indeed, its term depends on greatly varying data: the rate of growth, the variation in prices, the steadiness of markets, etc.

At all events, we must base our calculations on the period actually selected. In the case of coppice-with-standards, it is the rotation of the coppice if the number of standards is normal. When the standards reserved are either too abundant or insufficient, as many tables analogous to that given in Section 79 as may be necessary to obtain the number prescribed in the plan are drawn up. For high forest, whether of even-aged crops or worked under selection, it is the period prescribed by the working plan. This period may frequently be changed, but that is immaterial. The injury, the "*raison d'être*" of the valuation, having occurred now, the rotation current at the time must be adopted (*vide* Section 36). This is admitted even by the supporters of the so-called scientific method of valuation. "We must conform to the exploitability of the growing-stock as well as to general constitution. This presumes a normal condition and management. Should the state of the forest diverge from the normal, coupes must be so regulated as to bring it back to the normal." However, endeavours towards establishing the normal state can only be taken into account when the management has contemplated and expressly laid down the carrying out of such measures. Failing this, the actual situation shall be preserved without alteration.

Fluctuation of Rate.

We see, therefore, that the rate is subject to great variation. Cannon and Gazin, with the support of their great

experience, protested against the presumed invariability. "A fixed rate of interest for forests is an impossibility; depending as it does on more or less favourable terms of acquisition, skill in administration and demand, the rate must be ever and fundamentally subject to variation." And this must be the dictum of all impartial minds who seriously study the subject without prejudice.

35. A mean rate cannot be substituted for the special rate selected.—Various methods have been suggested to overcome the difficulty raised by the fluctuation of revenue and rate of interest, such as by adopting the average rate for real-estate or the normal rental of the country. This, however, is objectionable, as a particular point cannot be accurately settled by an average. Just as the inherent qualities of a property determine its purchase at 2, 3, 4 or 5 per cent., so a forest worked under a short rotation and consequently with a small volume of standing timber constitutes an investment at a higher rate than one worked under a long rotation with a considerable timber-capital. In many cases the proprietor suffers, especially where high-forest under a long rotation is in question. This is precisely the tendency of assurance policies, which stipulate a compulsory rate of 4 per cent. in the eventual settlement of claims.

Moreover, even in a definite region, such transactions do not continue under identical circumstances; they depend upon a number of contingencies: unforeseen and sudden need of funds, death of interested parties, personal considerations, etc., which, at each step, subvert the supposed immutability. How are the variations of supply and demand to be prevented, or even limited? And yet, every change in these entails fluctuation of interest. Section 42 reveals the flagrant errors suscitated by the conception of a uniform rate.

36. A maximum rate of interest.—The estimator is not at liberty to impose his ideal on the owner or to change the rotation:—

A method based on the maximum rate or the most profitable introduces a fictitious rotation in a forest which is actually managed under an entirely different age of exploitation.

The appraiser must base his calculations on facts, on the property of his client as it is actually managed, and not on

an ideal condition. Galmiche recently condemned this common error. "Estimation must proceed on the actual conditions of the forest, and not on those that might be set up under a different management. Once we allow considerations of altered methods to enter, we must give weight to the probable advantages of changes in the plan of standard selection, in the system, in clearing, etc., and an inquisition into questions of private convenience naturally follows." Of course, such improvements must be admitted when they are contemplated by the working plan, but they are, in that case, no longer alien grafts of the appraiser but the previously prescribed rules of management approved by the proprietor.

Revision or origination of a new treatment would provide an inexhaustible source of controversy and is inadmissible.

37. The Arbitrary Mixed System.—Certain products are estimated directly and the balance treated as productive capital.

Another ingenious system is the estimation of the crop at its market-value when it attains a merchantable age; younger crops and the soil are considered as capital invested at an average rate of interest, say 3 per cent., yielding products which will become saleable at a deferred date.

This method is arbitrary. A conventional value is bestowed on produce that is unsaleable or only exceptionally in demand.

Identical values are placed on all parts of the forest, which actually consists of a number of diverse crops harvested on sites changing from year to year, on varying and often exceedingly dissimilar soils. In actual practice a series of intricate calculations and confused arguments are involved; a truly laborious task before which any but the most expert mathematician might reasonably quail.

Relative Estimation.

38. Formula of relative estimation.—Several methods of soil valuation have been proposed. The one most commonly employed we will now examine. It will be seen that the stamp of scientific origin is more apparent than real; it is less trustworthy than a comparison with adjoining properties. However, though this method is defective for determining the rate of interest or the value of the soil when

employed alone, it is quite suitable for valuation of the yield.

In the first place we must clear the ground by defining precisely what is intended by "soil," there being a good deal of indecision as to the meaning attached to it. It has been used to convey the idea not only of the soil itself, but also of the exploitable material it bears : seedlings, rootstocks, etc., all of which, strictly speaking, constitute the capital invested. At other times it has stood for the land exclusively. We limit it strictly to this latter conception.

The soil itself can never represent the capital even when absolutely denuded, for to its price must be added brokerage, taxes, cost of planting, fencing, maintenance, etc.

FORMULA FOR THE MAJOR PERIODICAL YIELD.

A capital F at compound interest at the rate t during the rotation n of the forest in view, will amount to a sum equivalent to its periodical yield V, as shown by the formula :—

$$F = V \frac{1}{(1+t)^n - 1}$$

The value of the whole property C is the sum of the capital invested and the growing-stock S. Therefore $C = F + S$ in other terms :—

$$C = V \frac{1}{(1+t)^n - 1} + S$$

At the end of the rotation $S = V$ and therefore :

$$Cn = V \frac{1}{(1+t)^n - 1} + V = \frac{V[(1+t)^n - 1] + V}{(1+t)^n - 1} = V \frac{(1+t)^n}{(1+t)^n - 1}$$

Immediately after the harvest of the crop :—

$$Co = V \frac{(1+t)^n}{(1+t)^n - 1} - V = V \frac{(1+t)^n - [(1+t)^n - 1]}{(1+t)^n - 1} = V \frac{1}{(1+t)^n - 1}.$$

At the age m the growing-stock has attained the value that the capital F yields at compound interest: $F[(1+t)^m - 1]$ substituting F by its equivalent we get :—

$$Sm = V \frac{1}{(1+t)^n - 1}([1+t)] - 1] = V \frac{(1+t)^m - 1).}{(1+t)^n - 1).}$$

The total value of the property, capital *plus* increment, at m years is :—

$$Cm = F + Sm = V \frac{1}{(1+t)^n - 1} + V \frac{(1+t)^m - 1}{(1+t)^n - 1} = V \frac{(1+t)^m}{(1+t)^n - 1}$$

Formula for Thinned Forests.

When the working contemplates secondary fellings, as each of these thinnings recurs at intervals of n years, it is consonant with a growing-stock under a rotation of n years, but exploited at the age i, and the preceding formulas are applicable.

At the age n the capital-value of that portion of the property under the thinned wood is:—

$$V^1 \frac{(1+t)^n}{(1+t)^n - 1}$$

To obtain this value at the age m, as the capital will only start bearing interest in the year i—m, it must be discounted for that period :—

$$C^1 = V^1 \frac{(1+t)^n}{(1+t)^n - 1} \times \frac{1}{(1+t)^{i-m}} \quad \text{or} = V^1 \frac{(1+t)^{n-i+m}}{(1+t)^n - 1}$$

It is obvious that the capital-value of the thinning is not the result attained at compound interest for m years, as it does not date from the same moment as the final felling ; the interest begins from the date of exploitation, n—i years and then for m years.

This formula :—

$$C = V \frac{(1+t)^{n-i+m}}{(1+t) - 1}$$

is a general one.

It represents the total capital, including the capital invested and the growing-stock after m years, and corresponds either to the final felling or to the thinning carried out at the ages i. It will be further commented on in Sections 48 and 52 to 60. The latter will correct the tendency to wrong deductions based on the formula.

39. Errors of the method of relative estimation for ascertaining the soil value.—Relative estimation is correct in principle and the results obtained may be utilised, and indeed, will be utilised in subsequent calculations of this review, but conditionally on the *rate being obtained by positive estimation.*

A firm stand must, however, be made against its mischievous employment where it is inapplicable, notably to obtain the soil value. One of the chief disadvantages of its extravagant application is that extremely lengthy and complicated operations are involved.

Moreover, a serious drawback to the proposed formula is *the presence of t, that is to say, the unknown rate,* which is

precisely the value to be determined. Some arbitrary value, therefore, has to be selected for the capital first of all. To surmount the difficulty various values have been presumed for t, either in accordance with the custom of the locality or with the economical exploitability. This is, of course, again a purely arbitrary step. When applied to a wood under the selection system without very detailed regulations, the method becomes so arduous that its promoters spontaneously discard it : "Theoretically, the area should be split up into age-classes of say 20 to 20 years, in order to calculate the space occupied by a single tree of each class and its mean value. This would determine the capital-value and the length of the rotation. In view of the difficulty of such an operation, however, the exploitable age of woods of the same age and on similar soil must frequently be accepted."

Finally, the weariness of unending calculations predisposes the mind to suspect the excellence of the system. Those of its adherents who are but little accustomed to its use are tempted to *cook* the results so that they may agree with local market-rates. What then remains of the doctrine ? A mere scientific veneer. It will be further analysed in Section 42.

The rate being given the soil-value, considered as the capital producing the periodical revenue, is easily calculated by the equation (Section 38): $F = V \frac{1}{(1 + t) - 1}$. Let us take, for example, a coppice-wood producing :—

francs.		Productive capital. @ 3 per cent.	Productive capital. @ 4 per cent.
400	in 20 years	496	335
600	„ 25 „	548	360
925	„ 30 „	648	412
1,200	„ 35 „	661	407
1,450	„ 40 „	641	381

This does not mean that the land and the exploitable material it bears are together worth the amounts stated above in the locality. It is not sufficient merely to give t the value of 0·03 or 0·04 to obtain the total capital-value. Otherwise, the absurdity of the same land being worth 335 at 20 years of age and rising in value to 412 and falling again to 381 would be achieved. Land has its own intrinsic value independent of the date of exploitation, which does not vary with the age of the crops it bears. It cannot be

maintained that the *land* is worth 496 or 661 according as the crop is harvested at 20 or 35 years of age, when everyone in the locality would rate its value at 550.

The logical conclusion of such a statement would be the assertion that an area lying fallow to-day is worth nothing at all, whereas last year when in bearing it was worth many pounds and will ere long regain that level.

With a view to escaping this conclusion, some authors have postulated that the capital-value corresponds to the maximum arrived at by varying the age and the revenue. Thus, in the figures given above the *true* (?) capital would be 661 or 412 respectively at 3 per cent. and 4 per cent. But in most cases, at least in legal appraisement, the value of *t* is not fixed beforehand. Moreover, there still remains the difficulty which appears when the actual rotation does not coincide with that of the formula. When n is too high and intermediate products are exploited, the calculation of the capital-value becomes absurd; changes in market value, which cannot be foreseen so long in advance, throw the results into confusion. It is only applicable where forests are worked on a short rotation. There lies in a nutshell the weakness of the theory.

An uncompromising partisan of the system of relative estimation has asserted.—"By virtue of admitting the soil-value as the capital invested, $\frac{V}{(1 + t)^n - 1}$, the natural corollary that the soil has this constant value must also be conceded; consequently, any method which reduces it at intermediate ages must be rejected." Here is an implicit recognition of the absolute immutability of the value of the soil, for a definite period be it said. Indeed, whether the intermediate ages be taken in the middle of the contemplated exploitation or constitute as many different exploitations, the rate alone will be subject to correlated reaction, but the value of the soil will in no way be affected.

When in a particular locality agricultural land yields annually a practically constant return in quality, weight and money, its value can be pretty accurately stated by the formula $C = V \frac{1}{t}$. In other words, by multiplying the revenue by 33·33 when the usual rate of the locality is 3 per cent.

In fact, this formula differs only apparently from that previously given for arriving at the capital value with a periodically recurring revenue, as in the case of forests

the formulas become identical when n=1, as for land under annual crops.

The system is legitimate for lands bearing annually renewed crops ; it follows naturally from the general rule that property is estimated by the value of its products : a house according to its rental, cultivable soil on its harvest, etc. In the latter case, almost any farm hand can advise on the most suitable crop under given conditions and predicate almost to a nicety the resulting yield. With forest land, however, estimation is difficult owing to the yield varying according to the age of exploitation.

Referring to the table given above, it would be erroneous to assert that the soil-value at 35 years is 661. It would only be so if an annual revenue at 3 per cent. or 19·80 were derived. Should the revenue amount to 25 or 30, the soil would be valued at 833 or 1,000 respectively.

The formula $F=V\frac{1}{(1+t)^{n}-1}$ is exact and legitimate and its factor t must be made equal to x for n years, F and V being given. One must guard against attempting to obtain F by postulating v and t. This would be putting the cart before the horse.

It is often contended that the value of a property depends upon the use it is put to and that, consequently, it varies with the object of management. A confusion of terms is thereby introduced analogous to that discussed in Section 38 with regard to soil. It is essential that a distinction be maintained between the soil and the capital engaged in it, *after* addition either by human agency (sundry expenditure) or naturally (action of plants, physical or chemical modifications, etc.). The capital consists firstly of the soil, the value of which remains constant, and secondly of everything done to or brought on to it : draining improvements, manuring, breaking up, and especially the material produced on and exploited from it, the nature and prices of which are subject to the greatest fluctuations.

In regard to forests, the root-stocks, the seedlings or the standards are valued up to a certain point, according to the benefit expected from them or the use they are to be put to. Actually, they only constitute the material, it is the personal element in the different owners that would determine the variations in the results. Intelligence, knowledge, and skill : these are the prime factors.

Let us take as an example a piece of fallow, nearly sterile land put up for sale at a fixed rate per acre. We will suppose it to be practically homogeneous throughout as regards aspect, chemical composition and physical conditions. We will further assume that it is purchased in equal shares by a manufacturer, a sheep farmer and a sylviculturist.

The factory established by the first gives a return of 8 per cent. The second pastures sheep and realises 6 per cent. The last grows a pine forest, obtaining interest at 5 per cent. Experience teaches us that these high rates are precarious.

The manufacturer, overwhelmed by competitors, may be compelled to enter into liquidation; the factory falls into ruins and is eventually sold for the bare value of the soil. As regards the sheep-farmer, an infectious disease breaks out and destroys his herd; discouraged he leaves his land neglected, continuing payment of taxes at a pure loss. The pine forest also may suffer from an invasion of insects and bring in but 3 per cent.

In fine, the same soil, worth actually 100 francs and which had in no way been improved, by the method of relative estimation, would have been variously quoted at 800, 600, 500, 300 and 100 francs, and at last, at less than nothing. Can this be accepted?

One could quote numerous parallel cases. For instance, two co-heirs divide perfectly equally a recently-coppiced wood. One continues the management as simple-coppice returning 3 per cent., while the other allows standards to appear, which raises the interest to 4 per cent. Can we say that the value of the soil has been changed? The divergence might be much greater still, as between 2 to 5 per cent., for woods growing on two similar areas as high-forest under a rotation of 140 years and under a short rotation. In view of such discrepancies, the validity of the system of valuation of the soil by the capitalisation of the revenue can hardly be insisted upon any longer.

To sum up: The rate of interest is not fixed in any one locality. Essentially variable, it depends upon a number of contingencies—the system, the age and method of exploitation, the skill of the administrator, personal convenience, blunders of contractors, etc.

Direct valuation of the soil alone bears the test. The other theories are more or less clever devices, but are not

rational methods; they dwindle away before positive estimation, the purity of which will appear from the examples given in Sections 43 to 47.

Positive Estimation.

40. Positive Estimation.—The only one giving the true rate:—M. Hüffel has clearly stated the case: "Every appraisement necessitates the employment of a definite rate of interest. It is but equitable to employ that rate which reinstates the owner in a financial position as identical as possible with that he enjoyed before. Capitalisation, therefore, must be calculated at the rate of interest yielded by the forest prior to the injury." Now the only universally applicable solution is by positive estimation or the method of timber merchants, which is also that of speculators in landed property.

It is based on the following principles:—

41. Elements of positive estimation.—Analysis of merchantable products.—Differentiation of young unsaleable woods.—Soil valuation:—

The trees are enumerated and their volumes calculated. Fuel-yielding woods are valued by estimation as usual. The saleable products are divided into classes according to local custom and prices

A fundamental distinction must be established with regard to re-growth and seedlings still below a saleable size.

When they constitute the exploitable material, as in forests worked under natural regeneration, they must be valued and incorporated in the producing capital. When they form part of the final harvest, of the revenue, timber merchants neglect them entirely, or treat them as without value and reserve them to cover the contingencies to which such transactions invariably expose them, so as to be assured that any error will be on the right side.

In any case, this item is a very small one in high-forest grown for large timber, and even in a coppice-with-standards when the standards are numerous, and, therefore, it may be left out of account.

This simplification is admitted almost unanimously by economists, even those of the pseudo-scientific order: "Where the number of standards is large the young stems need not be considered, for the error thus introduced is smaller than that liable to creep in when estimating the old trees. Moreover,

by leaving out of account unsaleable produce we avoid the danger of giving the standing wood the same price as it will fetch after felling, though discounted for the number of years remaining before exploitation. The living tree, besides its value as merchandise, has a further value as a producer of revenue. Witness the result of a fire which may kill without destroying the tree, or even without causing exterior damage."

Nevertheless, at times thickets can no longer be neglected, for instance in the case of simple-coppice with a short rotation. The purchaser will then attribute to *young growing woods a speculative or prospective value*, dictated by his own experience or as prescribed in Section 55. Should considerable accuracy be desired, similar operations can be readily effected for regular high-forest (see Section 56), since the age-classes are localised within easily recognised limits. It is true the rate enters into these formulæ, and their solution will require trial interpolations; but the calculation is a simple matter, as the example in Section 45 will show.

The soil-value must be estimated by comparison with land of the same quality sold in the region, and with regard to the use for which it is fit: agrarian sometimes and nearly always for forestry. This is the method laid down for appraisers entrusted with the partition of woods under State management by the ministerial orders of 4th February 1813. Its credit has been in no way impaired by the mediocre results of more recent opposed theories. All facts reacting indirectly on the rate corroborate and justify this comparison.

The security of capital engaged in arable land is approximately equivalent to that of capital invested in forest property. Transactions in land are of constant occurrence. They rectify the data if necessary, furnish standard figures and record the variations in currency of land which affect real-estate in the region.

There can be no question that the system of direct estimation of the soil by comparison with neighbouring estates is the simplest.

Some authors have deemed it advisable to raise the rate of capitalisation for arable land in order to render it more applicable to forest property. They support their claims by the following considerations, some of which, together with their confutations, are borrowed from M. Reuss and M. Hüffel.

(1) The periodicity of timber-yield renders it inferior to the yearly return from field crops.

(2) Forests cannot be leased or pledged in view of the duration of the lease, absence of labour and the difficulty of drawing a clear line between the material forming the revenue and that composing the capital. The usufruct becomes an occasion for dispute.

(3) Forest products are subject to frequent fluctuations; prices are uncertain or contingent; that of oak-coppice (for cork) is essentially unstable.

(4.) Forests are exposed to offences; to damage by meteorological agencies and by game; to devastation by insects and by fire.

(5) Forests usually form large estates; to parcel them out, and even their sale, depreciates their value; this is a drawback, especially when they form part of a joint inheritance.

These objections are not incontrovertible and the retorts to each are appended in the same order.

(1) One is not compelled to harvest the yield of a forest at a fixed date; the time when prices are favourable can be selected, whereas the harvest of a field crop cannot be deferred nor even can its sale be postponed for long.

The forest can wait for years if necessary. It may be compared with a Savings Bank receiving capital and returning it with interest. No particular number of standards or particular age is immutably fixed.

(2) The inability to lease forests is rarely a drawback, whereas, on the other hand, valuable advantages are offered: small cost of management, if any; insignificant sundry expenses; a minimum of care and skill. The administration is simple and can be carried out by any one in possession of a rudimentary idea of sylviculture, or, at a pinch, intuition may suffice. It is not an occupation engaging one's full activities, and one can control the coupes though residing at a distance and in conjunction with other occupations. In fact, the wood grows by itself and acquires increment though treated with but little skill, or even with mere common sense.

This alone constitutes an incontestable superiority over agrarian cultivation. The latter is improved only at the expense of persevering, costly and laborious work; considerable knowledge is necessary as well as unrelenting vigilance. Finally, it depends directly on the continuous action of a floating capital; should it fail in any year the whole undertaking is compromised.

(3) The products of field crops are open to fluctuations of price by which they are more seriously affected than ligneous material. This vicissitude at times even entails the ruin of the cultivator. The matter is still further aggravated by the necessity of maintaining a rotation of crops, for the same crop does not prosper for more than a very few years on the same field. *Per contra*, forest growth is patently constant.

(4) Field crops are liable to accidental injury and devastation from the same causes as forests and, moreover, suffer as much, if not more, damage. In comparing an accumulation of huge trees suddenly overthrown by a cyclone or blackened by a fire with a season's field-crop struck down by hail or ruined by heavy rain this equality of the disaster is not immediately apparent. But the balance is re-established, at least in greater part, by the consideration of the value still attached to the ligneous products which, though greatly diminished by the cataclysm, are not annihilated, whereas the field crop, as a rule, is a total loss.

Again, invasions of insects or fungi are far more tenacious among field crops, and can scarcely be got rid of even at the expenditure of incessant care and ample funds; whereas in the case of forests, these attacks usually do not last long, are limited to a restricted area, and generally recur only after the lapse of considerable intervals.

The working capital is rapidly used up and exposed to considerable depreciation on a farm. During a war the capital, which includes stock, etc., not only lies idle but deteriorates; the forest, however, continues to put on increment.

(5) Though the large size of forest property may be inconvenient at times it offers, on that account, certain special advantages. Among the most esteemed may be quoted: sport, stability, moral influence, advantages of an æsthetic nature.

Further, heirs are not obliged to partition an inherited estate. According to individual choice one may retain the forest, the other receiving other property or a larger share of personality.

Summing up, it must be admitted that the advantages and drawbacks on either side are approximately balanced, even if the scale does not weigh in favour of forests.

One difficulty remains for consideration: that of finding in the neighbourhood arable soil comparable with forest soil. The difficulty exists certainly, but is not insuperable.

Mere peasants, devoid of all knowledge of geology, are able to value accurately the respective merits of two pieces of land. Their method, whether instinctive or reasoned, is immaterial, even though it consists in deducing the capital from the revenue. There is no reason, therefore, why professional appraisers or foresters, assisted by the experience of local cultivators, should not be capable of assigning to a particular forest its true position in the scale of fertility, in other words, in the order of soil-values, of the region. If the properties selected as types have been improved by various works of amelioration :—removal of stones, draining, breaking up, manuring, etc., it is a simple matter to take them into account. Actually, comparison is only difficult under exceptional circumstances, for instance in mountainous country. Here, as a rule, forests occupy precipitous and rocky slopes, greatly differing from the alluvium of the valleys.

Usually, however, there are pastures above them which can be easily appraised. It must be rare that some land cannot be found, whether bordering on or included in the forest, which is not too dissimilar to base a comparison on.

Moreover, sylviculture cannot be allowed to stagnate permanently while other branches of agricultural science are evolving. Agriculturists are endeavouring to devise means of indisputably determining with almost mathematical accuracy, the vegetative potentiality of soils. M. Varembey, elaborating Thaër's suggestion, is bringing agriculture into a place among the exact sciences ; his experiments have established a standard of fertility of soils for the principal cereals. A classification according to fecundity of soils should not prove more difficult in forests that in fields and the establishment of a standard scale may be impending.

M. Van Schermbeck has proclaimed its undoubted utility and foretold its future. It will be welcomed without hesitation and its results will possess the exactitude of analysis.

42. Comparison of resultant of positive estimation with that of other methods.—Errors arising from positive estimation are invariably less than those entailed by incertitude as to the choice of the rate of interest in other systems, or those consequent on mere suppositions, to say nothing of the risk of material falsification due to the accumulation of the subtle reasonings that characterise other theories. By virtue of its empirical character sylviculture cannot partake of mathematical perfection;

ocular, otherwise approximate, estimation must be admitted. Expert skill reduces these controversial elements and selects methods aiming at the elimination of discrepancies in the calculations. The partisans of the system of estimation based on the revenue confess to being frequently compelled to accept arbitrary data; wherein the system stands condemned. Nevertheless, it is advisable to study their methods of valuation and to compare them with those of the opposed thesis.

The most convenient system, and therefore the one most in vogue, accepts as *axioms, the precognition and the constancy of the rate of interest* in the particular region. When the outturn is uniform and periodic the value of the estate is equal to the capital which, invested in perpetuity, would yield at each term of exploitation an aggregate interest equivalent to the net revenue of the forest.

Example.—A forest yields a crop worth 1,120 francs every 25 years. The rate of interest for forests in the region is *postulated* as 4 per cent.

The capital producing 1,120 francs every 25 years at 4 per cent. is :—

(iii).*

1,120 × 0·6 = 672 francs.

When the outturn varies, the question of discount complicates the problem, but the principle remains unaltered.

This estimation is based on the immutability of the relations between the revenue and the capital. What are we to say of this dogma if the forest in question, originally worth 672 francs and still returning 1,120 francs, is sold for some reason or other for, say, 570 ?

The reply is :—"The rate remains unaltered, it is the value of the property which has suddenly increased in the hands of the purchaser; in short he has concluded a good bargain." Such an explanation, to say the least, is extremely feeble. Sections 32 and 35 sufficiently refute this dictum and it only finds place here in view of the extensive publicity it has acquired through most works bearing on the subject.

To avoid a similar error, an author who has deeply studied the question—M. Reuss—"selects from the several values

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* These Roman figures refer to tables in the Appendix and indicate which tariff the super- or subscribed number is obtained from.

that may be attributed to a soil that one which is derived from the free operation of supply and demand, termed by various authors, *true*, *real*, *absolute*, and *normal*. We, too, desire to adopt this method, since it alone is clear and as free as possible from the caprice and instability of human perception.

In practice this value is directly estimated with ease in the field, whereas other methods are founded on pure theory and are apt to vary with each separate case or estimator. This disparity has not escaped Mr. Reuss's vigilance and he discusses other values obtained in the following words:— "for instance values which arise in the course of transactions where one of the two contracting parties is influenced by personal considerations, is deluded by his own ignorance, etc. In these circumstances the interest still remains the rent of the soil; but it is no longer normal, it is relative to the way in which the soil has been estimated. Conversely, the capitalisation of the net revenue gives the relative and not the true value of the soil in question. The difference between the absolute and the relative values may, therefore, consist in a spurious estimate either of the rate of capitalisation, the cost of production or the net revenue. These errors in estimation, frauds or personal considerations, subvert the mechanism of the law of supply and demand." Multifarious causes determine the variation of the rate everywhere and in all that concerns money. No investment escapes from this instability, even the safest, based upon well established industries. Not uncommonly securities, not risky speculations, fluctuate from 4 to 20 per cent. in the space of a few years without any material modifications of dividend. Science and experience are no more capable of foreseeing these perturbations than they are of indicating an infallible method of computing their importance and even at times their direction. It follows that an appraiser's report based on the theories exposed above would require revision, if it were not, indeed, absolutely rejected, for the premises are doubtful and beyond control.

In the example taken, calculation of volume and estimation show that the capital-value 672 francs is made up of three elements: the standing trees (*réserves**)—238 francs, the potential stock (*ensouchement*)—220 francs and the soil—

* No good equivalent for the French terms *réserve* and *ensouchement* have been coined in the English language. For convenience the French words are used hereafter. The meaning of *ensouchement* is the stock of root-stocks (*souche*) and seedlings capable of eventually producing exploitable material.

214 francs. Starting with these data it will be useful to compare the results afforded by the several methods.

Positive Estimation.

Presuming that an error has been committed, while estimating the soil-value by direct comparison with neighbouring lands, let us see what results will be obtained by taking the largest possible error, say one of 50 per cent. either way, that is by adopting soil-values of 107 and 321 instead of 214.

Error of 50 per cent. in excess—

Soil	321
Ensouchement	220
Réserves	238
Capital invested	779
Revenue	1,120
Capital-value	1,899

Net rate of interest: $779\ (1 + x)^{25} = 1{,}899$
whence $x = 3{\cdot}62$ per cent.

Error of 50 per cent. in deficit—

Soil	107
Ensouchement	220
Réserves	238
Capital invested	565
Revenue	1,120
Capital-value	1,685

Net rate of interest: $565\ (1 + x)^{25} = 1{,}685$
whence $x = 4{\cdot}46$ per cent.

Thus, with so large an error in valuation, which may be accepted as the maximum, divergence from the true rate of 0·38 to 0·46 per cent., or an average of only 0·42 per cent. is entailed, which is inconsiderable. With any other method of estimation so important an initial error would involve far greater inaccuracies.

If we substitute an initial error of 25 per cent. in place of one of 50 per cent. in the above calculations, the rate obtained would be 3·80 and 4·21 per cent. This average error of 0·2 per cent. is almost negligible.

Let us see what results are obtained in the calculation of the injury caused when adopting such initial errors. This, indeed, is the chief consideration in the present study. For the sake of convenience we will take the simplest case : that of a coppice under a rotation of 25 years, destroyed at the age of 6. This solved by the second method of Section 64 is :—

Initial errors postulated.	Rate per cent.	Calculation.	Values of growing woods or injury caused.	Error per 100.
		(iii) (i)	Francs.	
Correct rate of interest .	4	1,120 × 0·6 (1·265 − 1)	178	—
Rates resulting from presumed initial error of 50 per cent. when directly estimating the soil-value.	3·62	1,120 × 0·695 (1·238 − 1)	185	+4
	4·46	1,120 × 0·504 (1·299 − 1)	169	−5
Rates corresponding to the corrected figures of the relative estimation ; error of 25 per cent.	3·82	1,120 × 0·684 (1·251 − 1)	182	+2
	4·23	1,120 × 0·553 (1·281 − 1)	174	−2

These errors are insignificant and negligible.

Relative Estimation or by Revenue.

System based on the constancy of the rate of interest.— Let us presume the same maximum error of 50 per cent. in place of the correct rate of 4 per cent., we then have 2 per cent. or 6 per cent. and the property will be valued at :—

$$\overset{}{1{,}120\text{ frs.}} \times \overset{\text{(iii)}}{1{\cdot}561} = 1{,}748\text{ frs. or } 1{,}120\text{ frs.} \times \overset{\text{(iii)}}{0{\cdot}304} = 340\text{ frs.}$$

Here we find a great divergence, and yet these rates of 2 per cent. and 6 per cent. are by no means unheard of and are frequently met with in neighbouring estates.

Possibly an experienced Forester will instinctively realise that neither of the two values are correct and he will then change them, in other words, will falsify his figures to arrive

at those he feels are more suitable. This is precisely the danger which Section 39 adumbrates and which justly throws suspicion on the system.

Let us, however, accept more favourable circumstances and presume that the skill of the experts has rectified the first errors and that a rate of 3 per cent. or 5 per cent. has been adopted, thus :—

$$1{,}120 \text{ frs.} \times \overset{\text{(iii)}}{0{\cdot}914} = 1{,}024 \text{ frs. or } 1{,}120 \text{ frs.} \times \overset{\text{(iii)}}{0{\cdot}419} = 469 \text{ frs.}$$

The results are no longer ridiculous. Nevertheless, the figures still differ enormously from the true soil-value and, moreover, a mere rough approximation to the rate of interest is not admissible under the pretext that an error of 1 per cent. entails a tolerable deviation of but one-half or one-third in the total capital. The latter is not the goal or at least it is but an intermediate one; what is aimed at is an exact basis for ulterior determinations. But the rate is the principal factor of all calculations in financial matters and an error of 1 per cent. is sufficient to abort the whole computation. Now, where forests are concerned it is so difficult to judge of analogous conditions and to form well founded and unassailable opinions, that an estimator who selects the rate cannot guarantee his choice within 1 per cent., with a possible exception in the case of simple-coppice wood.

Let us verify this with the test applied for the absolute estimation :—

Initial errors postulated.	Rate.	Calculation.	Value of growing woods or injury caused.	Resulting errors in amount of injury corresponding to the same initial errors. Adopting a constant rate.	By direct estimation of the soil-value.
	Per 100.	(iii) (i)	Francs.	Per 100	Per 100
Correct rate . . .	4	1,120 × 0·6 (1·265—1)	178	...	...
Rates resulting from presumed initial error of 50 per cent.	2	1,120 × 1·561 (1·126—1)	220	+24	+4
	6	1,120 × 0·304 (1·418—1)	142	—20	—5
Corrected rates corresponding with an initial error of 25 per cent.	3	1,120 × 0·914 (1·194—1)	199	+12	+2
	5	1,120 × 0·419 (1·34—1)	160	—10	—2

Comparison between the figures in the last two columns renders further comment unnecessary.

BY CALCULATION OF THE SOIL-VALUE AND OF THE RATE.

Another somewhat ingenious method has been advocated and merits a reference, though it too admits arbitrary figures.

"Both the value of the soil together with the potential stock (*ensouchement*) and the rate of interest at which it operates being unknown, the rate of production of woody material at a fixed age must be ascertained and it must be presumed that the capital engaged generates interest at the same rate."

The procedure is as follows :—

Let us take as example a coppice-with-standards area worked on a rotation of 25 years.

The coupe yields from coppice			200 frs.
From standards	100 Oaks worth	544 frs.	
	90 Beech, etc.	152 „	
			696 „

It is presumed that the coppice realises 40 francs at the age of 12 years, the minimum age at which it reaches commercial value.

I.—UPPER STORY.

The standards consist of 1—Oaks, 2—Beech and miscellaneous. The girth increment is ascertained from a study of the annual rings to be 0·013 m. per annum. *We admit* (arbitrarily) that the increment is constant throughout the life of the tree. With these data one can prepare either a diagramatic curve or the appended table, showing for each species the price of each girth-class of standard.

VALUATION OF STANDARDS.

Girth in Metres.	Oak.	Beech and miscellaneous.
	Francs.	Francs.
0·30	0·12	0·12
0·40	0·16	0·16
0·50	0·40	0·36
0·60	0·64	0·56
0·70	1·12	0·84
0·80	1·60	1·12
0·90	2·40	1·36

At the beginning of the rotation the overwood consisted of :—

$$\left.\begin{array}{l}\text{100 Oaks valued at 152 frs.}\\ \text{90 Beech, etc., valued at 38 frs.}\end{array}\right\}\text{190 francs.}$$

The formula for compound interest in the case of the periodic exploitation is :—

$$\text{Co.} = \frac{V}{(1+t)^n - 1} \text{ or } (1+t)^n = \frac{\text{Co.} + V}{\text{Co.}}.$$

Oak Standards.—If the oaks alone produce the revenue of 544—152=392 francs, the rate for them would be :—

$$(1+t)^{25} = \frac{152 + 392}{152} \overset{(i)}{=} 3{\cdot}58 \text{ or } 5{\cdot}25 \text{ per cent.}$$

Twenty-five years ago the average price of these trees was $\frac{152}{100} = 1{\cdot}52$ francs. This corresponds in the above table with a circumference of 0·78 m. and an age of 60 years, admitting a constant increment of 0·013 per annum.

If the value of the soil occupied by these oak trees had borne interest at 5·25 per cent. it would have amounted to :—

$$\text{Co.} = \frac{152}{1{\cdot}0525^{60} - 1} \underset{(i)}{=} \frac{152}{21{\cdot}54 - 1} = \frac{152}{20{\cdot}54} = 7 \text{ francs.}$$

The capital producing 392 francs is therefore no longer 152 francs but 152+7, the rate is therefore :—

$$(1+t)^{25} = \frac{7 + 152 + 392}{7 + 152} \overset{(i)}{=} 3{\cdot}46;$$

or 5 per cent. and again the soil-value having operated during 60 years at only 5 per cent., to produce 152 francs it must have been greater than 7.

$$\text{Co.} = \frac{152}{1{\cdot}05^{60} - 1.} \underset{(i)}{=} \frac{152}{18{\cdot}68 - 1{\cdot}} = \frac{152}{17{\cdot}68} = 9 \text{ francs.}$$

This value must be substituted for that previously arrived at and the rate again calculated :—

$$(1+t)^{25} = \frac{9 + 152 + 3}{9 + 152} \overset{(i)}{=} 3{\cdot}44;$$

or still 5 per cent. The rate remaining the same 9 francs is accepted as the soil-value.

Miscellaneous Standards.—Similarly, were the 90 miscellaneous trees the sole producers of the revenue of 114 francs their rate of production would be :—

$$(1 + t)^{25} = \frac{38 + 114}{38} = 4 \text{ or } 5{\cdot}75 \text{ per cent.}$$

The average value of one of these trees at the beginning of the rotation was $\frac{38}{90}=0{\cdot}42$ francs, corresponding with a girth of 0·53 and consequently an age of 41 years.

If the soil occupied by these standards had operated at a rate of 5·75 per cent. to produce 38 francs in 41 years it would have been worth :—

$$\text{Cd.} = \frac{38}{1{\cdot}0575^{41}-1} = \frac{38}{9{\cdot}94-1} = \frac{38}{8{\cdot}94} = 4 \text{ francs.}$$

The generating capital being therefore no longer 38 francs but 38 + 4 ; the rate is therefore :—

$$(1+t)^{25} = \frac{4+38+114}{4+38} \underset{}{=} \overset{(i)}{3{\cdot}71} \text{ or } 5{\cdot}25 \text{ per cent.}$$

But the soil having operated only at a rate of 5·25 per cent. its value was :—

$$\text{Cd.} = \frac{38}{1{\cdot}0525^{41}-1} = \frac{38}{8{\cdot}19-1} = \frac{38}{7{\cdot}19} = 5 \text{ francs.}$$

This sum being substituted for that previously arrived at we recalculate the rate at which the soil and the potential stock operate to procure a revenue of 114 during the rotation.

$$(1+t)^{25} = \frac{5+38+114}{5+38} = 3{\cdot}65, \text{ or still } 5{\cdot}25 \text{ per cent.}$$

We therefore accept 5 francs as the value of the soil occupied by the miscellaneous standards.

II.—Coppice.

We now proceed to ascertain by analogous calculations the value of the soil together with the *ensouchement* producing coppice to the value of 40 francs in 12 years and 200 francs at the age of 25, or in other words, putting on a revenue increment of 160 francs in 13 years.

1st Trial.

$$(1+t)^{13} = \frac{40+160}{40} = 5, \text{ corresponding with 13 per cent.*}$$

$$\text{Ct.} = \frac{40}{1{\cdot}13^{12}-1} = \frac{40}{\underset{(i)}{4{\cdot}335}-1} = \frac{40}{3{\cdot}335} = 12 \text{ francs.}$$

* Table I is carried only to 5 per cent., but an easy calculation will obtain the higher rates as shown in the introductory observations to the table.

2nd Trial.

$$(1+t)^{13} = \frac{12+40+160}{12+40} = 4{\cdot}08, \text{ corresponding with } 11{\cdot}5 \text{ per cent.}$$

$$\text{Ct.} = \frac{40}{1{\cdot}115^{12}-1} = \frac{40}{\underset{(i)}{3{\cdot}68-1}} = \frac{40}{2{\cdot}68} = 15 \text{ francs.}$$

3rd Trial.

$$(1+t)^{13} = \frac{15+40+160}{15+40} = 3{\cdot}9, \text{ corresponding with } 11 \text{ per cent.}$$

$$\text{Ct.} = \frac{40}{1{\cdot}11^{12}-1} = \frac{40}{\underset{(i)}{3{\cdot}498-1}} = \frac{40}{2{\cdot}498} = 16 \text{ francs.}$$

4th Trial.

$$(1+t)^{13} = \frac{16+40+160}{16+40} = 3{\cdot}86, \text{ still corresponding with } 11 \text{ per cent.}$$

We therefore accept 16 francs as the value of the soil occupied by the coppice. Therefore, the total capital invested at the beginning of the rotation was :—

Soil under standards	9 + 5	30
Do. coppice	16	
Standards		190
TOTAL .		220 francs.

It is presumed that this capital produces in 25 years firstly, the difference between the values of the standards at the end and at the start : 696—190=506 francs ; secondly, the sale price of the coppice, *viz.*:—200 francs, or in all : 706 francs. The rate of interest would therefore be :—

$$(1+t)^{25} = \frac{220+706}{220} = 4{\cdot}2, \text{ or } 6 \text{ per cent.}$$

Criticism of the Estimation.—On the face of it these results are surprising.

1. Forests of this nature returning 6 per cent. are rare. Simple-coppice woods of oak and beech realising 11 per cent. on the capital invested do not exist.

2. In coppice-with-standards, it is rather the overwood that tends to raise the average of revenue.

3. The low valuation of the soil at 30 francs is amazing. In certain poor regions the value per hectare of inferior denuded soil may fall as low as 30 francs, but an area of a quality sufficiently good to yield 706 francs in 25 years without any tending is worth at least 3 or 4 times that sum.

4. Nowhere in the calculations does the value of the potential stock find place. The cost of planting, say, 10,000 plants at 22 francs per 1,000, or 220 francs should be added to the estimate. These are, indeed, the figures adopted by most expert authors: Puton, Broilliard, Détrie and F. Cardot. At first sight, this valuation of the *ensouchement* appears excessive as it gives to a forest after exploitation a value equal to twice that of a similar area of soil after clearing. Nevertheless, it is, if anything, a moderate estimate. It must be admitted that 10,000 root-stocks per hectare are not necessary for a satisfactory re-growth, one-third of that number would suffice; but firstly, artificial plants are far less robust than coppice-shoots from a vigorous root-stock, whose numerous deep and spreading roots fully utilise the soil without fear of frost or drought; secondly, in many regions the dangers to which plantations are exposed are such that in the final issue success can only be reckoned on for about half the plants. Can one maintain that the productiveness of 5,000 transplants at an actual cost of 220 francs will exceed or even equal that of 3,333 thirty-year old root-stocks? The latter undoubtedly will be given the preference. In the Haute-Saone region 5 plants per root-stock are insisted upon, and at this rate the valuation of the soil with the *ensouchement* would amount to 250 francs instead of only 30 francs.

5. The data employed are correct; they agree with those prevalent in the wood and timber trade and have elsewhere yielded accurate results. It is therefore the method which is faulty. Moreover, by adopting any other units similar consequences are attained, as will be seen a little further on.

6. The multiplicity of operations is a great objection and leads to errors.

7. The figure arrived at in each equation corresponds approximately only to the round number of francs accepted as decimals are omitted to avoid complication. It also only approximates to a precise rate of interest, as

tables are usually prepared in gradations of $\frac{1}{2}$ per cent., even the most complete do not consider fractions less than $\frac{1}{4}$. Further, such tables do not embrace figures for 1 to 15 per cent., nor are they usually framed for more than 100 years, consequently a sequence of small errors are committed of which neither the total nor the direction can be gauged.

8. It is not very practicable to fell so large a number of trees, or even to use Pressler's increment-borer, in order to obtain the average increment. Moreover, such measurements cannot be guaranteed to a millimetre; and yet, in the example given, an error of one millimetre converts the age of an oak of 0·78 m. from 60 to 49 years, and similarly of a miscellaneous tree of the same girth from 41 to 33 years.

The soil-values depending on these figures are also commuted from 9 to 19 francs and from 5 to 12 francs, *i.e.*, more than doubled.

In the method of absolute estimation the same error, not being multiplied, would remain insignificant and would not perceptibly affect the result.

9. The period, the increment of which is measured, being diminished, the influence of the possible error is correspondingly increased. In the example under consideration, it is increased by about one-half for the coppice, as it was reckoned for only 13 years and not for 25 years. (See also Section 37.)

10. As the starting point of all the calculations the choice falls upon the value corresponding firstly, to a certain girth, and secondly, to a certain age. The determination of the first point is one of extreme delicacy, and further, no forester will admit a constant rate of increment for all species throughout the life of the tree.

From these considerations we may deduce that discrepancies in estimation are the inevitable result of the imperfection of instruments such as the human eye. When definite conclusions are in question, such as those we have seen obtained by absolute estimation, the ultimate calculations of injury are not seriously affected by such small errors, and there is even a possibility of compensation. But when, as in the case of relative estimation, an example of which we have just discussed, they form the basis of the calculations, and the error, however minute at the start, is multiplied by a series of factors, the resultant is manifestly falsified. In other words, identical initial errors have vastly different effects in the two methods.

Demonstration with the same prices applied to the same coppice-with-standard forest.

Economic Condition of the Forest.

	Soil	168	francs.
Material	*Ensouchement* estimated cost of a plantation	220	,,
	Standards originally enumerated in the coupe	190	,,
	Capital invested .	578	francs.
Revenue	Trees 696	896	,,
	Coppice 200		
	Capital value .	1,474	francs.

Rate of interest: $578\ (1+x)^{25}=1474$; whence $x=3{\cdot}75$ per cent.

Now let us compare the results of identical divergence, in excess or in deficit, introduced in the one method and the other. Presuming, for instance, the most favourable conditions and a consequent increase of one quarter in production, *i.e.*, in quantity and therefore in total value, without affecting the soil-value. By virtue of improved quality and yield the rate of interest naturally rises. Let us test this.

Positive Estimation.

	Soil valued by comparison with neighbouring lands .	168	francs.
	Ensouchement.—This is not modified as it rests upon the cost of plantation independently of conditions of growth	220	,,
	Standards . . . . $190+\frac{190}{4}$ . . .	238	,,
	Capital invested .	626	francs.
Revenue	Trees . . $696+\frac{696}{4}=870$	1,120	,,
	Coppice . . $200+\frac{200}{4}=250$		
	Capital value .	1,746	francs.

Rate of interest: $626\ (1+x)^{25}=1{,}746$; whence $x=4{\cdot}25$ per cent.

The rate has risen which agrees with the argument.

Estimation by Revenue.

Coppice.—Value of yield at 12 years—

$$40 + \frac{40}{4} = 50 \text{ francs.}$$

and at 25 years : $200 + \frac{200}{4} = 250$ francs.

Overwood.

Annual girth increment as obtained from observation of annual rings :—

$$0{\cdot}013 + \frac{0{\cdot}013}{4} = 0{\cdot}016.$$

Valuation of Standards.

Girth metres.	Oak francs.	Beech, etc. francs.
0·30	0·15	0·15
0·40	0·20	0·20
0·50	0·50	0·45
0·60	0·80	0·70
0·70	1·40	1·05
0·80	2·00	1·40
0·90	3·00	1·70

Standards at the beginning of Rotation.

100 Oaks worth . . . $152 + \frac{152}{4} = 190$ francs.

90 Beech, etc., worth . . $38 + \frac{38}{4} = 48$ „

238 francs.

Standards after 25 years.

100 Oaks worth . . . $544 + \frac{544}{4} = 680$ francs.

90 Beech, etc., worth . . . $152 + \frac{152}{4} = 190$ „

870 francs.

Calculation of value of soil occupied by oak standards.

$$(1 + t)^{25} = \frac{190 + 490}{190} = 3{\cdot}58 \text{ or } 5{\cdot}25 \text{ per cent.}$$

Average value of one tree $= \frac{190}{100} = 1{\cdot}9$ francs, which corresponds to a girth of 0·78 m. and an age of 49 years.

$$Cc. = \frac{190}{1{\cdot}0525^{49} - 1} = \frac{190}{12{\cdot}27 - 1} = \frac{190}{11{\cdot}27} = 17 \text{ francs.}$$

2nd Trial.

$$(1 + t)^{25} = \frac{17 + 190 + 490}{17 + 190} = 3{\cdot}367 \text{ or } 5 \text{ per cent.}$$

$$Cc. = \frac{190}{1{\cdot}05^{49} - 1} = \frac{190}{10{\cdot}921 - 1} = \frac{190}{9{\cdot}921} = 19 \text{ francs.}$$

3rd Trial.

$$(1 + t)^{25} = \frac{19 + 190 + 490}{19 + 190} = 3{\cdot}344 \text{ or still } 5 \text{ per cent.}$$

The soil-value of the area occupied by oaks is therefore 19 francs.

Miscellaneous Standards.

$$(1 + t)^{25} = \frac{48 + 142}{48} = 3{\cdot}96 \text{ or } 5{\cdot}75 \text{ per cent.}$$

Average value of a single tree $= \frac{48}{90} = 0{\cdot}53$ francs corresponding to a girth of 0·53 m. and an age of 33 years.

$$Cd. = \frac{48}{1{\cdot}0575^{33} - 1} = \frac{48}{6{\cdot}33 - 1} = \frac{48}{5{\cdot}33} = 9 \text{ francs.}$$

2nd Trial.

$$(1 + t)^{25} = \frac{9 + 48 + 142}{9 + 48} = 3{\cdot}49 \text{ or } 5 \text{ per cent.}$$

$$Cd. = \frac{48}{1{\cdot}05^{33} - 1} = \frac{48}{5 - 1} = \frac{48}{34} = 12 \text{ francs.}$$

3rd Trial.

$$(1 + t)^{25} = \frac{12 + 48 + 142}{12 + 48} = 3{\cdot}366 \text{ or still } 5 \text{ per cent.}$$

The value of the soil occupied by the miscellaneous standards is therefore 12 francs.

Coppice.

$$(1 + t)^{13} = \frac{50 + 200}{50} = 5 \text{; corresponding to 13 per cent.}$$

$$Ct. = \frac{50}{1 \cdot 13^{13} - 1} = \frac{50}{4 \cdot 335 - 1} = \frac{50}{3 \cdot 335} = 15 \text{ francs.}$$

2nd Trial.

$$(1 + t)^{13} = \frac{15 + 50 + 200}{15 + 50} = 4 \cdot 08 \text{ or } 11 \cdot 5 \text{ per cent.}$$

$$Ct. = \frac{50}{1 \cdot 115^{12} - 1} = \frac{50}{3 \cdot 68 - 1} = \frac{50}{2 \cdot 68} = 19 \text{ francs.}$$

3rd Trial.

$$(1 + t)^{13} = \frac{19 + 50 + 200}{19 + 50} = 3 \cdot 95 \text{ or } 11 \text{ per cent.}$$

$$Ct. = \frac{50}{1 \cdot 11^{12} - 1} = \frac{50}{3 \cdot 498 - 1} = \frac{50}{2 \cdot 498} = 20 \text{ francs.}$$

4th Trial.

$$(1 + t)^{13} = \frac{20 + 50 + 200}{20 + 50} = 3 \cdot 857 \text{ or still } 11 \text{ per cent.}$$

The value of the soil under coppice is therefore 20 francs. The capital invested is:—

Soil under standards . . .	=19+12	} 51 francs.
Do. do. Coppice .	20	
Standards		238 „
		289 francs.

The capital produces in 25 years—

Standards	870—238=632	} 882 francs.
Coppice	250	

The rate of interest would be :—

$$(1 + t)^{25} = \frac{289 + 882}{289} = 4 \cdot 052 \text{ or } 5 \cdot 75 \text{ per cent.}$$

Now, with the former figures a rate of 6 per cent. resulted and, therefore, this system shows a diminished rate in spite of an increased yield. It arrives at a value of 51 francs per hectare for a soil capable of producing 882 francs in 25 years, which is patently absurd. Such results, as well as a system of such complication must be rejected.

43. Positive estimation of a simple coppice :—

Example.—One hectare of simple coppice, rotation 25 years.

Soil, estimated by comparison with neighbouring lands	100	francs.
Ensouchement.—As before	220	"
Capital invested .	320	francs.
Revenue after 25 years, according to fellings in the forest, or in any adjacent forests .	400	"
TOTAL .	720	francs.

Rate of interest (*vide* Section 38) $F = V\frac{1}{(1+t)^n - 1}$;

otherwise: $F[(1+t)^n - 1] = V$

or $F(1+t)^n = V + F$.

Substituting the figures of our example:—

$$320\ (1+t)^{25} = 320 + 400 = 720$$

$$(1+t)^{25} = \frac{720}{320}$$

$$\text{Log. } (1+t) = \frac{\log. 720 - \log. 320}{25}$$

$$t = 3{\cdot}29 \text{ per cent.}$$

All exploitation entails expenditure. We will presume the latter amounts yearly to 3 francs, covering taxes, part pay of a guard and sundry works. From this figure, however, is deducted accessory revenue derived from game fees, grass, etc., amounting to 1·62 francs, leaving a net charge of 1·38 per annum.

The corresponding capital at 3 per cent. is :—

$1{\cdot}38 \times \frac{100}{3} = 46$ francs when the charge is permanent.

If the charges continue for the first rotation of 25 years to disappear thereafter, the formula is :

$$C = A\frac{1}{t}\left(1 - \frac{1}{(1+t)^{25}}\right)$$

Which in our example becomes :

$$C = 1{\cdot}38 \times 17{\cdot}413 = 24 \text{ francs.}$$

At first sight the latter figure appears preferable as it does not pledge the future, nevertheless, the former alone is justifiable as it involves the same idea of perpetuity as the other term (320) of the equation. Adopting the figure 46, the exploitation becomes, so to speak, automatic, that is to say, absolutely regular. At the end of the rotation the wood is cut over and re-growth comes up of itself. The capital continues operating exactly as at the start. The owner realises

400 francs periodically. Had 24 francs only been accepted, the same amount would have to be deducted at the beginning of each period and this periodic revenue would only be 400—24 on the invested capital of 320 francs.

Calculations are thereby complicated, whereas, with the initial and non-recurring inclusion of 46 all complexity vanishes and the invested capital remains throughout 320+46.

It is not generally admitted that the charges capitalised at compound interest can be dealt with similarly to the capitalised soil-value, yet this is the only system that will stand close examination.

One of the principles of appraisement in case of damage consists in the maintenance of the working as it was previously; we cannot introduce a supposititious sale, but we are at liberty to refer to the previous purchase for data. When its present proprietor bought the forest, he had to pay :—

I	For the soil with its *ensouchement*, the seedlings, standards, in short for the whole property, in our example . $\left\{\begin{matrix}100\\220\end{matrix}\right\}$	320 francs.
II	The value of tho ripe crop : 400 francs. As it was resold at once the item need not find place here.	
III	To secure the sustained working the new owner may be said to have advanced a sum equivalent to the capitalised charges	46 „
	Total expenditure .	366 francs.

Each year he pays out in taxes, to the guard, etc., the interest 1·38 francs. Strictly speaking these items do not accumulate, but *for the purchaser* the results are similar, in other words, the permanent investment of 46 francs would ensure interest for payment of 1·38 francs annually in perpetuity. His purchase may therefore be said to have cost him 320+46. Of these two sums the one, in the shape of the soil, produces incessantly and the other in deposit with a bank is shorn every year of its interest and brought back to its original figure. But, *from the owner's point of view*, the two represent a single homogeneous sum which he could have applied to any other speculation and from which he is entitled to expect

$$(320+46)\ [(1+t)^{25}-1].$$

This for him constitutes the capital invested and it must form the basis for the calculation of the rate of interest. Should he re-sell the forest, he will receive in the first place, 320 francs from the purchaser, and secondly, the deposit of 46 francs will be set free. It is, therefore, truly 320+46 which were invested.

Had the revenue derived from these accessory sources exceeded the annual charges there would be no hesitation in adding the surplus to the revenue. Supposing a 25 years' lease for the collection of resin, dead wood, grass, etc., the lessee paying in advance all charges and in addition a sum of 1·38 francs a hectare per annum, these payments would be represented by a capitalised sum of 46 francs received at the beginning of the rotation by the owner, and the capital invested would accordingly be 320—46. Logically, therefore, there should be no distinction when the sum of charges exceeds the accessory revenue.

A little further on this point will be mathematically established.

1st Method.—The rate to be ascertained is the relation between the invested capital, 366 francs, and the periodic revenue, 400 francs, falling due every 25 years. The formula being :—

$$F = V \frac{1}{(1+t)^{25}-1};$$

substituting the figures of one example we get :—

$$366 = 400 \frac{1}{(1+t)^{25}-1} = \frac{1}{(1+t)^{25}-1} = \frac{366}{400} = 0{\cdot}915.$$

If we glance at the figures in table III, against the age 25, we find in the column under 3 per cent. the figure 0·9143.

Three per cent. is therefore the rate of interest for the coppice under consideration. The formula could have been written :—

$$[320\ (1+t)^{25}-1] + 46\ [(1+t)^{25}-1] = 400;$$

that is to say, that the sum of the compound interest on the value of the estate (320) and the capitalised charges (46) produces the revenue (400).

2nd Method.—This is merely a variant of the first, but the calculations assume a different form. It solves the question : What is the rate of interest of a forest whose capital value is 366 and which yields 400 every 25 years? The yield 400 is multiplied successively by each of the

factors in table III corresponding to 25 years till a resultant of 366 is attained, which fixes the rate.

Let us try with the factor of 4 per cent. :—

$$400 \times \overset{\text{(iii)}}{0{\cdot}6} = 240.$$

The resultant is too low, consequently the rate is too high.

We therefore repeat with the factor corresponding to 3 per cent.;

$$400 \times \overset{\text{(iii)}}{0{\cdot}9143} = 366.$$

3 per cent. is therefore the correct rate.

3rd Method.—Another and perfectly logical way arrives at the same figure as follows: At the beginning of the rotation, or, to be quite accurate, at the end of the first year, the owner pays 1·38 francs for sundry charges.

Had there been no such charges he would save 1·38 francs which, put out at compound interest, would by the end of the rotation, *i.e.*, in 24 years, have amounted to $1{\cdot}38(1+t)^{24}$.

The following year he again disburses 1·38 francs which at the end rotation at compouud interest would amount to $1{\cdot}38\ (1+t)^{23}$, and so on to the end of the rotation, when he will pay a final 1·38, which will not bear interest. The total of the payments and their interests are represented by :—

$$1{\cdot}38\ [\ (1+t)^{24}+(1+t)^{23}+\ \ldots\ (1+t)+1] = 1{\cdot}38\ \frac{(1+t)^{25}-1.}{t}$$

Added to the capital invested this becomes :—

$$320\ [\ (1+t)^{25}-1]+1{\cdot}38\ \frac{(1+t)^{25}-1}{t} = 400.$$

which by trials gives a rate of 3 per cent. as was of course to be expected, for capitalisation of the charges is attained by multiplying the sum by $\frac{1}{(1+t)^{25}-1}$. This gives :—

$$1{\cdot}38\ \frac{(1+t)^{25}-1}{t} \times \frac{1}{(1+t)^{25}-1} = \frac{1{\cdot}38}{t}$$

that is to say, the very fraction adopted at the beginning of the section.

4th Method.—Usually the following formula is used :—

$$320\ (1+t)^{25} = 320+400-46 = 674.$$

$$\text{whence, } (1+t)^{25} = \frac{674}{320} = 2{\cdot}106$$

$$\text{whence, } x = 3{\cdot}02 \text{ per cent.}$$

This process furnishes a result often sufficiently approximate but not absolutely accurate. The resulting figures do not permit regression to the original data of the problem, that is to say, the initial and final values of the coupe, for which a verifying calculation is available.

Verification.—The rate of 3·02 per cent. gives the values of the property at 0 and 25 years, as:—

$$f = 400 \times \overset{\text{(iii)}}{0{\cdot}907} = 362{\cdot}8.$$

$$F = 400 \times 0{\cdot}907 \times \overset{\text{(i)}}{2{\cdot}1046} = 763.$$

The correct values are 366 and 766.

For the same ages the rate of 3 per cent. arrives at:—

$$\left.\begin{aligned} f &= 400 \times \overset{\text{(iii)}}{0{\cdot}9143} = 366 \\ F &= 400 \times 0{\cdot}9143 \times \overset{\text{(i)}}{2{\cdot}0938} = 766 \end{aligned}\right\} \text{the correct figures.}$$

Therefore, the fourth process is inferior to the other three. Its equation can be shown thus:—

$$320 \left[(1+t)^{25} - 1 \right] = 400 - 46.$$

This means that the capital (320) at compound interest yields the revenue (400) diminished by the charges capitalised, but bearing in mind that the said capital only bears interest from the moment of the felling of the coupe, or *beginning with the second rotation.* Now this is insufficient and does not truly represent the exploitation. In order to obtain a revenue of 400 francs the yearly expenditure of 1·38 francs, corresponding to a capital of 46 francs, has had to be met from the *beginning* of the first rotation and not *at its close.*

44. Positive estimation of a coppice-with-standards crop.—Analysis of the exploitation:—From the prescription laid down, the marking register and a reconnaissance in the field, the following data are obtained. At each felling, say every 25 years, 120 first-rotation, 60 second-rotation and 10 third-rotation standards are found on the ground. One hundred and twenty new, 60 first-rotation and 10 second-rotation standards are marked for reservation. Consequently, the stock of over-wood to be removed consists of 60 first-rotation, 50 second-rotation and 10 third-rotation standards. The average prices are 0·15 francs for the new standards, 2 francs for those of first rotation, 10 francs for second-rotation and 25 francs for the oldest. The coppice is valued at 250 francs.

Positive Estimation.

	Soil, estimated by a comparison with neighbouring lands	150 francs.
Material .	*Ensouchement* calculated as before (see Section 42)	220 "
	Standards enumerated—	
	120 new standards at 0·15 = 18	
	60 2nd-rotation standards at 2 = 120	238 "
	10 3rd-rotation standards at 10 = 100	
	Capital invested . .	608 francs.

Revenue, estimated according to the marking prescriptions:—

Revenue.	2nd-rotation standards 120—60 = 60 at 2 =	120	
	3rd-rotation do. 60—10 = 50 at 10 =	500	
	4th-rotation do. 10— 0 = 10 at 25 =	250	
	Total standards . .	870	
	Coppice, omitting the new standards marked for reservation	250	
			1,120 francs.
	TOTAL .		1,728 francs.

Rate of interest:—

$$608\ (1+x)^{25} = 608 + 1{,}120 = 1{,}728\ ;$$

by logarithms, or by interpolations with the help of the tables, we find $x = 4{\cdot}25$ per cent.

The annual charges amount to 4·30 francs, but after deduction of accessory revenue from game fees, grass, dog-wood, etc. (1·70) francs the sum is reduced to 2·60 francs. This capitalised at 4 per cent. is:—

$$2{\cdot}6 \times \frac{100}{4} = 65 \text{ francs.}$$

The net rate of interest is obtained as in Section 43.

1st Method.—The capital invested amounts to:—

Soil	150	
Exploitable material	458	673 francs.
Capitalised charges	65	

$$673 = 1{,}120\ \frac{1}{(1+x)^{25}-1},$$

$$\text{whence } \frac{1}{(1+x)^{25}-1} = \frac{673}{1{,}120} = 0{\cdot}6008\ ;$$

which corresponds to a rate of 4 per cent.

2nd Method.—Applying the factor in table III applicable for 25 years—

$$1{,}120 \times 0{\cdot}6003 = 673$$

Which agrees with the known capital invested.

3rd Method :—

$$608\ (1+x)^{25} = 608+1{,}120 - 65 = 1{,}663.$$

$$(1+x)^{25} = \frac{1{,}663}{608} = 2{\cdot}735.$$

corresponding with a rate of 4·10 per cent.

Verification.—With a rate of 4 per cent. the capitalised values from 0 to 25 years are :—

$$1{,}120 \times \overset{\text{(iii)}}{0{\cdot}6003} = 673$$

$$1{,}120 \times 0{\cdot}6003 \times \underset{\text{(i)}}{1{\cdot}6658} = 1{,}120$$

or the same figure as before.

With a rate of 4·10 per cent. the capital becomes 671

which gives $1{,}120 \times \overset{\text{(iii)}}{0{\cdot}58} = 649{\cdot}6$

$$1{,}120 \times 0{\cdot}58 \times \underset{\text{(i)}}{1{\cdot}735} = 1{,}127.$$

These numbers differ from those which it was sought to obtain, therefore 4 per cent. is the rate to be adopted.

45. Positive estimation of a simple coppice, with cleanings.—When cleanings have to be considered, the calculation of the rate of interest is greatly complicated because the intermediate sales, though under the same rotation as the final fellings, start at a different date. The outcome of each bears interest from the date of its realisation, but this is at the year 0 of the rotation for the final felling and the year m for the thinning.

The latter must therefore be capitalised for n—m years.

The calculation is carried out by interpolating a probationary rate and judging whether it is too high or too low by the result. To restrict the number of trials the following operation may be adopted :—

Data.—Simple coppice yielding 400 francs in 25 years.

Thinnings at the age of 17 years yielding 80 francs.

1st Method.—We start with an approximate estimation, presuming the revenue to be 400+80.

Soil with its potential stock, as before		100 francs.
		220
Capital invested		320 francs.
Revenue: Final felling	400	
Revenue: Thinnings	80	480
TOTAL		800 francs.

From the formula: $320\ (1+x)^{25} = 800.$
We obtain: $(1 + x)^{25} = 2{\cdot}50.$

In table I against 25 years under 3·75 per cent. we find the figure 2·51 which is very close to that arrived at above. The sale price of the thinnings (80 francs) employed in the calculation, however, is too low since it was realised 8 years earlier and has since borne interest; consequently, the quotient obtained is also too low. By interpolating 3·75 per cent. and then 4 per cent. the true rate will be obtained, or at least it will lie between those figures:—

		Trial with rate of			
		4 per cent.		3·75 per cent.	
Soil estimated as before		100 francs.		100 francs.	
Ensouchement estimated as before (Section 42)		220		220 ,,	
Capital invested		320 francs.		320 francs.	
Revenue at age 25. Final felling	400		400		
Thinning capitalised for 8 years at 4 per cent. and 3·75 per cent.	110	510 ,,	107	507 ,,	
		830 francs.		827 francs.	

If the correct rate is 3·75 per cent. or 4 per cent., then $320\ (1{\cdot}0375)^{25}$ or $320\ (1{\cdot}04)^{25}$ must produce 827 and 830, respectively.

The resultants actually are:—

(i)

$$320 \times 2{\cdot}51 \;\;= 803$$
$$320 \times 2{\cdot}666 = 853.$$

The capitalised values obtained, 827 and 830, are about half-way between the two resultants, consequently, the true rate is about half-way between 3·75 and 4 per cent.

2nd Method.—Applying the general formula in Section 38—

$$C = V\,\frac{(1+t)^{n-i+m}}{(1+t)^{n}-1}.$$

In the present instance m=o.

Any rate is taken, say 4 per cent.:—

$$\begin{array}{l} \text{(iii)} \\ 400 \times 0{\cdot}6 = 240. \\ \ \ 80 \times 0{\cdot}6 \times \underset{\text{(i)}}{1{\cdot}369} = 66. \end{array}$$

The capital invested F is represented by the equation :—

$$F = 400\,\frac{1}{(1+x)^{25}-1} \times 80\,\frac{(1+x)^{25-17}}{(1+x)^{25}-1}.$$

Adding therefore the two sums 240 and 66 to verify them with the known capital 320 we find it falls short by 14; consequently the rate (4 per cent.) selected is too high. We try again with 3·75 per cent.—

$$\left.\begin{array}{l} \text{(iii)} \\ 400 \times 0{\cdot}6622 \phantom{\times 1{\cdot}343} = 265 \\ \ \ 80 \times 0{\cdot}6622 \times \underset{\text{(i)}}{1{\cdot}343} = \ \ 71 \end{array}\right\}\ \text{336 or 16 too much.}$$

The true rate is therefore about half-way between 3·75 and 4 per cent.

Supposing the annual charges, after deduction of accessory revenue, amounts to 1·75 francs, the capitalised value at 3·5 per cent. amounts to 50 francs and the capital invested becomes 320+50=370 francs.

The formula including intermediary outturn is :—

$$F = 400\,\frac{1}{(1+x)^{n}-1} + 80\,\frac{(1+x)^{n-i}}{(1+x)^{n}-1}.$$

Interpolating 3·5 per cent. as the rate we obtain—

$$F = 400\,\frac{1}{1{\cdot}035^{25}-1} + 80\,\frac{1{\cdot}035^{25-17}}{1{\cdot}035^{25}-1}.$$

$$\begin{array}{l} \text{(iii)} \\ 400 \times 0{\cdot}733 \phantom{\times 1{\cdot}317} = 293 \\ \ \ 80 \times 0{\cdot}733 \times \underset{\text{(i)}}{1{\cdot}317} = \ \ 77 \\ \hline \phantom{400 \times 0{\cdot}733 \times 1{\cdot}317 = }\ 370 \end{array}$$

The exact capital invested resulting, the true rate is 3·5 per cent.

3rd Method.—

$$\text{Capital} = 320 = 400 \frac{1}{1{\cdot}035^{25}-1} + 80 \frac{1{\cdot}035^{25-17}}{1{\cdot}035^{25}-1} - \frac{1{\cdot}75}{0{\cdot}035}.$$

$$\begin{array}{lrr} & \text{(iii)} & \\ & 400 \times 0{\cdot}733 & = 293 \\ + & 80 \times 0{\cdot}733 \times 1{\cdot}317 & = 77 \\ & \text{(i)} & \overline{} \\ & \text{(iii)} & 370 \\ - & 1{\cdot}75 \times 28{\cdot}57 & = 50 \\ & & \overline{} \\ & & 320 \end{array}$$

320 which is also correct.

Other methods, of which two of the most used are quoted below as examples, must be rejected as erroneous.

I. Under the pretext that the rotation is the same for the thinning and the final felling, it has been proposed to amalgamate them—

$$F = 320 = (400 + 80) \frac{1}{(1 + x)^{25} - 1}\text{; whence } x = 3\tfrac{3}{4} \text{ per cent.}$$

But the two yields do not operate from the same date, for the thinning it comes into being 8 years earlier; consequently this method gives too low a rate.

II. A still lower rate is obtained by restricting the calculations to the periodical yield alone, extracting its annual equivalent and deducting the annual charges.

The equation $320\ (1+x)^{25}\ 320+400$ gives the net rate $x=3{\cdot}32$ per cent.

The annual equivalent of the yield 400 francs is $320 \times 0{\cdot}0332 = 10{\cdot}62$ francs.

Deducting the charges, the net revenue is $10{\cdot}62 - 1{\cdot}75 = 8{\cdot}87$ francs and the ultimate rate is lowered to

$$\frac{8{\cdot}87}{320} = 2{\cdot}77 \text{ per cent.}$$

46. Positive estimation of high-forest with thinnings and artificial regeneration.—We have progressed from the simple to the complex, from the easily estimated simple-coppice to the more complicated high-forest with intermediary fellings, and now we can proceed to the intricate case where several thinnings intervene before the final felling. Let us take as example the pine forest analysed in Section 107. It is of the average type and returns a sustained periodical revenue.

Analysis of the yield of a pine wood under a 60 years' rotation.

Thinning at	12 years' yielding	. .	4 francs.
Do.	20 do.	. .	8
Do.	28 do.	. .	35
Do.	36 do.	. .	175
Do.	44 do.	. .	552
Do.	52 do.	. .	625
Final felling at	60 do.	. .	2,333

The expenses of regeneration after each final felling amount to 110 francs and the annual charges to 4·50 francs.

It is pre-eminently in the case of high-forest, where the invested capital is pledged and the revenue accumulated for so considerable a period, that it would be neither rational nor accurate to merely sum up the revenue of the several fellings at the end of the rotation. The returns of the thinnings must be calculated at compound interest from the dates of realisation to the close of the period, for woods are akin to sums of money placed at interest (Sections 61, 63). To these is added the value of the final coupe and, that of minor produce, resin, etc. The formula stated in Section 38 is applicable. A rate of 4 per cent. may be interpolated first.

$$F = 4\frac{(1+x)^{60-12}}{(1+x)^{60}-1} + 8\frac{(1+x)^{60-20}}{(1+x)^{60}-1} + 35\frac{(1+x)^{60-28}}{(1+x)^{60}-1}$$

$$+ \ldots\ldots + (2{,}333 - 110)\frac{1}{(1+x)^{60}-1}$$

(i)

4	×	6·57	=	26·2
8	×	4·801	=	38·3
35	×	3·508	=	122·7
175	×	2·563	=	448·5
552	×	1·873	=	1,033·8
625	×	1·369	=	855·5
2,333	− 110		=	2,223·

(iii)

4,748 francs × 0·105 = 498·5 francs.

Deduct annual charges $4{\cdot}5 \times \frac{100}{4}$ = 112·5 „

Capital invested . . 386 francs.

Positive Estimation.

Soil, valued by comparison with lands in the vicinity		.	60 francs.
Potential Stock	Seedling stock	.	110 „
	Ensouchement of broad-leaved underwood	.	33 „
	Capital invested	.	203 francs.

The capital invested (203) is far smaller than that arrived at (386) by taking a 4 per cent. interest; it follows that the rate selected is far too small. Five per cent. may therefore be tried—

$$
\begin{array}{rcrcr}
 & & \text{(i)} & & \\
4 & \times & 10{\cdot}401 & = & 41{\cdot}6 \\
8 & \times & 7{\cdot}04 & = & 56{\cdot}3 \\
35 & \times & 4{\cdot}765 & = & 166{\cdot}7 \\
175 & \times & 3{\cdot}225 & = & 564{\cdot}3 \\
552 & \times & 2{\cdot}183 & = & 1{,}205{\cdot} \\
625 & \times & 1{\cdot}477 & = & 923{\cdot}1 \\
2{,}333 & - & 110 & = & 2{,}223{\cdot} \\
\end{array}
$$

$$\overset{\text{(iii)}}{5{,}180 \times 0{\cdot}0566} = 293 \text{ francs.}$$

$$\text{Deduct annual charges } 4{\cdot}5 \times \frac{100}{5} \quad . \quad . = 90 \quad „$$

Capital invested . 203 francs.

The correct capital being here reproduced exactly the rate of 5 per cent. is correct. It is this rate and not that on the gross capital (*i.e.*, undiminished by the charges) that must be adopted, since in forests of this nature the charges assume exceptional importance and become indispensable. In addition to the usual charges there are expenses on fire protection, preparation of the soil for sowing, etc. Moreover, such crops, hardy and unexacting as regards soil, are rarely established on any but the poorest land, the taxes on which are insignificant; this factor disappears, at least becomes negligible, in face of the other charges which, so to speak, form part and parcel of the treatment.

We may now further verify the operations as follows:—

Positive estimation of the pine forest.

Soil	.	60 francs.
Ensouchement	.	143 „
Charges (at 5 per cent.)	.	90 „
Capital invested	.	293 francs.

Capital invested	.	293 francs.
Revenue calculated at 5 per cent. as previously	.	5,180 „
Total	.	5,473 francs.

Now 293 at a rate of 5 per cent. for 60 years is—

$$293 \times 1{\cdot}05^{60} = 5{,}473.$$

5 per cent. is therefore the correct rate of interest.

Section 50 will demonstrate the correctness of this method, as well as its constancy in face of perturbations arising from unforeseen circumstances.

47. Positive estimation of high-forest with thinnings and natural regeneration.—In the last example we considered a pine forest where the natural regeneration is not complete at the end of the rotation, and has therefore to be supplemented by planting. In any case a complete cycle is achieved in 60 years. We will now review the case of oak and beech high-forest regenerated in 140 years.

Analysis of the Exploitations.

At the age 140 a seeding felling is carried out over the area, followed 5 years later by a secondary felling to further expose the seedlings that have sprung up, and at the age of 150 the final felling takes place at which the remaining mature trees are removed. The control-book and the stock registers show that the working plan has been adhered to and that the growing stock is in a normal condition and capable of indefinitely and constantly producing the following yield:—

At 40	years a thinning	bringing in . .	60 francs.
60	ditto	ditto	120
80	ditto	ditto	250
100	ditto	ditto	600
120	ditto	ditto	800
140	years a seeding felling		2,000
145	„ secondary		3,000 „
150	„ final		3,000 „

The last two items being realised at 145 and 150 years only, they will be *discounted* for 5 and 10 years respectively to assimilate them to the other figures which are calculated to 140 years.

In practice complete regeneration would often require more than 10 years, and thinnings at closer intervals would be preferable. The above figures, however, have been adopted in order to reduce the number of operations.

Besides, the figures selected actually occur in several working plans and most authors have made use of similar ones.

Positive estimation.

We will first try a rate of 2·5 per cent.

Soil, by comparison with lands in the vicinity	150 francs.
Ensouchement	10 „
Seedlings, calculated on the basis of the cost of planting as before	220 „
Saplings left to merge into the new stock .	30 „
Capital invested .	410 francs.

		(i)			
Revenue	60 ×	11·814	= 708·8		
	120 ×	7·21	= 865·1		
	250 ×	4·4	= 1,100		
	600 ×	2·685	= 1,611		
	800 ×	1·639	= 1,311·1	12,591 francs.	
	2,000 ×	...	= 2,000		
		(ii)			
	3,000 ×	0·884	= 2,652		
	3,000 ×	0·781	= 2,343		
			Total .	13,001 francs.	

If the rate selected, 2·5 per cent., is correct, then the product of $410 \times 1{\cdot}025^{140}$ should equal 13,001. The resultant is actually 13,005, which is sufficiently close to admit 2·5 per cent. as the correct interest for the gross revenue and even for the net revenue, if the annual charges do not exceed 3·7 francs. The verification is by multiplying the gross revenue by the factor of 2·5 per cent. in the table III and the resultant should equal the capital invested.

(iii)

$$1{,}259 \times 0{\cdot}03255 = 410.$$

$2\frac{1}{2}$ per cent. is therefore the correct rate of interest.

48. Remarks regarding the fellings carried out after the end of the rotation.—Though the secondary and final fellings take place 5 and 10 years after the seeding felling, their rotation is nevertheless one of 140 years, for at the last rotation they occurred 5 and 10 years in arrears and will do so again at the next. Their yields, however, will only be realised later and so the sums must be discounted for 5 and 10 years, respectively.

By adopting another line of argument we reach the same conclusion. The seeding, secondary and final fellings real-

ising respectively 2,000 francs at 140 years, 3,000 francs at 145 years, and 3,000 francs at 150 years, may be reckoned as having occurred simultaneously at 140 years and realising an aggregate of 6,995 payable at once. This aggregate has three constituents: 200 francs, being the sale price of the seeding felling first sold; 2,652 francs, the discounted value of the secondary felling to be sold 5 years hence for 3,000 francs; and 2,343, the discounted value of the final felling to be sold 10 years hence for 3,000 francs.

The substitution of a fictitious rotation of 150 or 145 years corresponding with the date of the final or the secondary felling has also been suggested.

Thus, supposing that the capital relating to the sales of the major fellings are desired at a date 10 years after the final felling.

With an imaginary rotation at the age of the final felling the calculation would be :—

$$\frac{2{,}000\ (1 + t)^{(150-140)+10} + 3{,}000\ (1+t)^{(150-145)+10}}{(1+t)^{150} - 1} + \frac{3{,}000\ (1+t)^{(150-150)+10}}{(1+t)^{150} - 1}$$

or

$$\begin{array}{lclcl} & & \text{(i)} & & \\ 2{,}000 & \times & 1{\cdot}639 & = & 3{,}278 \\ 3{,}000 & \times & 1{\cdot}448 & = & 4{,}344 \\ 3{,}000 & \times & 1{\cdot}28 & = & 3{,}840 \\ \hline \end{array}$$

$$11{,}462 \times \underset{\text{(iii)}}{0{\cdot}02525} = 290 \text{ francs.}$$

The same, without change in the rotation, stands :—

$$\frac{2{,}000\ (1 + t)^{(140-140)+10} + 3{,}000\ (1+t)^{(140-145)+10}}{(1+t)^{140} - 1} + \frac{3{,}000\ (1+t)^{(140-150)+10}}{(1+t)^{140} - 1}$$

$$= \left\{\begin{array}{lclcl} & & \text{(i)} & & \\ 2{,}000 & \times & 1{\cdot}28 & = & 2{,}560 \\ 3{,}000 & \times & 1{\cdot}131 & = & 3{,}393 \\ 3{,}000 & \times & 1 & = & 3{,}000 \\ \hline & & & & 8{,}953 \end{array}\right.$$

$$8{,}953 \times \underset{\text{(iii)}}{0{\cdot}0325} = 290 \text{ francs.}$$

The secondary and final fellings can also be considered as thinnings after the term of the rotation, conformably to

Section 54. All these methods, however, arrive, within a small fraction, at the same total when calculating the value of the estate. Preference should therefore be given to the simplest. In any case the formula remains unchanged, *viz.*:—$C = V \dfrac{(1+t)^{n-i+m}}{(1+t)^{n}-1}$, the correct powers being substituted for n, i, and m. See the table in Section 56.

49. Selection of rate.—In estimating damages a round figure for the rate should be preferred for the following reasons:—

Special reasons for the present work.

1. It is customary to omit fractions of less than one half in the rate of interest. Rates of 3·29 or 4·25 for instance complicate calculations.

2. A treatise should aim at simplicity and clearness. In the examples offered the rate of interest produces the exact totals representing the gross value of the estate and the initial and final values of area, and the operations are therefore more readily grasped.

General reasons.

3. The estimation is more equitable if it allots to the victim of the fire full compensation under the same conditions under which his money is invested.

However, some authors are of opinion that the taxes, which form the major portion of the charges to be deducted from the gross revenue, should be considered as a personal charge on the proprietor by virtue of his ownership, and not on the estate itself. This is supported by the law in Italy, some of the cantons of Switzerland, certain states of Germany, the United States of America and to a certain extent in England. A similar tendency may be traced elsewhere; in France there is much talk of taxation on income. In countries where this tax is legal this factor might be contested. Introduced into the calculations, it causes the indemnity to vary rather with the status of the owner than in proportion to the actual damage done.

50. Variation of the rate in harmony with the cultural system, the rotation and prevailing prices.—It is interesting to observe the concordance of the development of the returns with the improvement in treatment. Our examples chosen among typical forests, that is to say, average and characteristic of the several kinds of systems, demonstrate this point.

An intelligent sylviculturist will obtain from the soil results far superior to those achieved by a proprietor working by rote or neglectful in the tending of his woods. High-forest with a lengthy rotation, which outside mountainous regions is practically beyond the means of any one but the State or wealthy townships, naturally bears the lowest rates of interest in virtue of the long intervals between the principal fellings. The big timber, which high-forest alone can furnish, increases the outturn and yields the highest *forest rental*, but at the expense of the rate of interest on the invested capital.

Simple-coppice on poor soil will usually return 3 per cent. but the same would yield 3½ per cent. if the trouble of carrying out a thinning is taken, so as to give the shoots the air and sun necessary for their active growth.

A slightly better soil and especially a more perfect system, exacting, it is true, more supervision and a little skill, will produce 4 per cent.

Finally, where the climate and the demand allow the choice of species yielding from an early age valuable products, such as telegraph-posts, mine-props, hop-poles, etc., even an indifferent soil will produce an extremely remunerative growing-stock.

With a little foresight an enterprising owner will obtain 5 per cent. at the risk it is true of possible failure and of danger from fire, but constant and enlightened supervision and even some skill in marking are required. Here, as elsewhere, ability and determination lead to profit, but not without contingent risks.

Objection may perhaps be taken to these general principles of estimation for high-forest under a long rotation in view of the impossibility of guaranteeing the constancy of prices and consequently of the revenue for such lengthy periods. The yield and outturn in materials only can be estimated with fair accuracy; but the mutation of prices and values is beyond human prescience. Yet the rate and, consequently, the amount of the indemnity is directly affected by such mutations.

The valuer can only retort that he has taken all possible precautions to avoid error, that he has based his calculations upon the data available at the time the injury was caused, and that he cannot be held responsible for contingencies impossible to foresee. Forestry is essentially empirical and does not boast of mathematical precision.

Another argument, however, is of a nature to completely silence further scruples. In positive estimation, variations due to fluctuations in price are reduced to a minimum; discrepancies far from being multiplied, on the contrary, tend to counterbalance; consequently, errors remain within permissible limits. In order to dissipate all doubts, it will be as well to demonstrate this assertion here, though the question of damages is fully dealt with later.

1st Hypothesis:—In order to assume the most unfavourable conditions, we will suppose a fall in prices of 25 per cent. immediately after the estimation and continuing indefinitely. Let us take as example the high-forest quoted in Section 46 and the injury assessed in the first case in Section 110.

The analysis of exploitation is as follows:

			Francs.
At 12 years a thinning yielding		. . .	4
20	ditto	$. 8 - \frac{8}{4} =$	6
28	ditto	$. 35 - \frac{35}{4} =$	26
36	ditto	$. 175 - \frac{175}{4} =$	131
44	ditto	$. 552 - \frac{552}{4} =$	414
52	ditto	$. 625 - \frac{625}{4} =$	469
60 the final felling	.	$.2223 - \frac{2223}{4} =$	1,667

Positive estimation.

By trial interpolations the rate is ascertained to be 4·39 per cent.

		(i)		
4	×	7·897	=	31·6
6	×	5·593	=	33·6
26	×	3·962	=	103
131	×	2·807	=	367·7
414	×	1·9894	=	823·7
469	×	1·4103	=	661·4
1,667	.	. .	.	1,667

3,688 × 0·08297 (iii) = 306 francs.

Deduct capitalised charges: $4 \cdot 5 \times \frac{100}{4 \cdot 39}$ = 103 „

Capital invested . . . 203 francs.

It is striking that the enormous fall of 25 per cent. in the market prices has had but a slight effect upon the rate. Whereas, with any other method, a deep impression would have been made on the invested capital and thereafter on the exploitation, with the method advocated the invested capital remains intact, and under the most unfavourable circumstances the rate of interest is influenced to the extent of 0·61 per cent. only.

And now as to the indemnity. To enable us to realize the effect we will proceed to compare the results at the full price and after the fall of 25 per cent.

1. *Depreciation*—

		(ii)			
6	×	0·709	=	4·3	
26	×	0·503	=	13·1	
131	×	0·357	=	46·8	
414	×	0·2534	=	104·9	466·9
469	×	0·18	=	84·4	
1,667	×	0·128	=	213·4	

2. *Re-stocking*—

As in section 110		.	.	220	234·1
110	×	0·128	=	14·1	
			Total .		701

Deduct

4. *Salvage*— 12

5. *Thinnings*—

		(ii)			
$4 - \frac{4}{4} = 3$	×	0·597	=	1·8	
6	×	0·424	=	2·5	
26	×	0·301	=	7·8	314
131	×	0·213	=	27·9	
414	×	0·152	=	62·9	
$2,079 - \frac{2,079}{4} = 1,559$	×	0·128	=	199·1	

Damage caused . 387 francs

The assessment of damage done (Section 110) at the original prices before the fall of 25 per cent. amounted to 403·80 francs. The difference is only 16·80 francs or 4 per cent., which is almost negligible. No other system would offer such an assurance against the adverse influence of unforeseen events.

In the two following hypotheses, neither the rate nor the indemnity changes appreciably. A review of them is

nevertheless useful rather as examples of positive estimation under conditions of difficulty than for the sake of cumulative proof.

2nd Hypothesis.—The fall in prices does not last, at the end of 60 years, *i.e.*, during the second rotation, they resume their original level.

1st Rotation.—The rate is ascertained to be 4·39 per cent.

$$
\begin{array}{rcccrl}
 & & \text{(i)} & & & \\
4 & \times & 7{\cdot}897 & = & 31{\cdot}6 & \\
6 & \times & 5{\cdot}593 & = & 33{\cdot}6 & \\
26 & \times & 3{\cdot}962 & = & 103{\cdot}0 & \\
131 & \times & 2{\cdot}807 & = & 367{\cdot}7 & \Big\}\ 3{,}688 \text{ francs.} \\
414 & \times & 1{\cdot}9894 & = & 823{\cdot}7 & \\
469 & \times & 1{\cdot}4103 & = & 661{\cdot}4 & \\
1{,}667 & & \ldots\ldots & = & 1{,}667{\cdot}0 &
\end{array}
$$

As the revenue of 3,688 does not recur under the same conditions, instead of being capitalised it must be discounted for 60 years at 4·39 per cent.

$$3{,}688 \times \underset{\text{(ii)}}{0{\cdot}07652} = 282{\cdot}20 \text{ francs.}$$

Deduct the charges 4·5 to be disbursed annually for 60 years.

$$4{\cdot}5\left[\frac{1}{0{\cdot}0439}\left(1-\frac{1}{1{\cdot}0439^{60}}\right)\right] = 4{\cdot}5 \times 21{\cdot}075 = 94{\cdot}80$$

187·40 francs.

2nd and following rotations.—As in section 46. The net capital 203 francs which will not operate till the lapse of 60 years, is equivalent now at 4·39 per cent. to—

$$203 \times \underset{\text{(ii)}}{0{\cdot}07652} \quad . \quad . \quad 15{\cdot}60 \text{ francs.}$$

Total equivalent to capital invested . 203 francs.

The mean rate for the aggregated exploitation is obtained as follows:—

At the end of the 1st rotation the gross revenue is	. 3,688 francs.
Deduct the charges (94·8) put out at 4·39 per cent. for 60 years, 94·8 × 13·256 (i)	. 1,257
Remainder .	2,431
Add the capital requisite to ensure ulterior revenue .	203
	2,634 francs.

$$(1 + x)^{60} = \frac{2{,}634 + 203}{203} = 13{\cdot}975$$

Corresponding to a rate of 4·49 per cent. (Table I).

As in the first case, the difference in the indemnity calculated with this average rate and with the rate at the original prices is small.

3rd Hypothesis.—The fall occurs when the wood has reached the age of 32 and persists till the end of the rotation, when prices rise again to their former level and some time later fall once more.

For the sake of simplicity let us suppose that these alternations recur punctually during the course of each rotation—

At 12 years	a thinning yielding	. . . .	4 francs
20	ditto	. . . .	8
28	ditto	. . . .	35
36	ditto	. $175 - \frac{175}{4} =$	131
44	ditto	. $552 - \frac{552}{4} =$	414
52	ditto	. $625 - \frac{625}{4} =$	469
60	a final felling	. $2{,}223 - \frac{2{,}223}{4} =$	1,667

Starting from the date of the fire occurring at the 12th year, the pine forest continues to yield interest for 20 years at 5 per cent. and then falls to another rate, which by trial interpolation is discovered to be 4·5 per cent. It does not exactly coincide with the average rate, but it is better to consider it so as the difference is not great, and to maintain the distinction, without being of much practical value, would cause unnecessary complications of merely theoretical importance.

Rate of					(i)		
5 per cent.	for 20 years	4	×	2·653	=	10·6
4½	ditto 28	10·6	×	3·43	=	36·4
5	ditto 12	8	×	1·796	=	14·4
4½	ditto 28	14·4	×	3·43	=	49·4
5	ditto 4	35	×	1·215	=	42·6
4½	ditto 28	42·5	×	3·43	=	145·8
at 4½ per cent.		131	×	2·876	=	376·8
		414	×	2·022	=	837·1
		469	×	1·422	=	666·9
		1,667	.	.	=	1,667
						3,847

(iii)

$$3{,}847 \times 0{\cdot}0768 = 295{\cdot}5$$

The annual charges may be separated into two portions, the one bearing interest at 5 per cent. for 32 years:—

$$4{\cdot}5\left[\frac{1}{0{\cdot}05}\left(1-\frac{1}{1{\cdot}05^{32}}\right)\right]=4{\cdot}5\times 15{\cdot}803 \qquad =71{\cdot}12$$

and the other at 4·5 per cent. for 28 years. The latter must be assimilated by discounting for 32 years at 5 per cent.

$$4{\cdot}5\left[\frac{1}{0{\cdot}045}\left(1-\frac{1}{1{\cdot}045^{28}}\right)\right]\frac{1}{1{\cdot}05^{32}}=4{\cdot}5\times 15{\cdot}743\times \overset{\text{(ii)}}{0{\cdot}21}=\underline{14{\cdot}88}$$

$$86$$

This amount—86 francs—at the end of the rotation at the average rate becomes—

$$86 \times \overset{\text{(i)}}{14{\cdot}027} = 1{,}206$$

The capital capable of returning 1,206 every 60 years at the rate of 4·5 per cent. is—

$$1{,}206 \times \overset{\text{(iii)}}{0{\cdot}07676} = 92{\cdot}5$$

$$295{\cdot}5 - 92{\cdot}5 = 203$$

As the resultant equals the capital invested the mean rate is really 4·5 per cent.

The indemnity is calculated as follows:—

I.—Depreciation—

The rate is still 5 per cent.	$8\times0{\cdot}677=5{\cdot}4$	450·7
	$35\times0{\cdot}458=16{\cdot}1$	
Between the 2nd and 3rd thinnings the fall occurs and the rate sinks to 4½ per cent.	$131\times0{\cdot}348=45{\cdot}6$	
	$414\times0{\cdot}2445=101{\cdot}2$	
	$469\times0{\cdot}172=80{\cdot}7$	
	$1{,}667\times0{\cdot}121=201{\cdot}7$	

II.—Re-stocking—

As in section 110 . .	220	233·3
110 × 0·121 (ii)	= 13·3	

Total . 684

	Brought forward .	684
Deductions—		
III.—Salvage—	12	
IV.—Thinnings—	(ii)	
At 5 per cent.—	$4 \times 0{\cdot}557 = 2{\cdot}2$	
At 4½ per cent. from the 2nd thinning onwards.	$6 \times 0{\cdot}415 = 2{\cdot}4$	
	$26 \times 0{\cdot}292 = 7{\cdot}5$	299
	$131 \times 0{\cdot}205 = 26{\cdot}8$	
	$414 \times 0{\cdot}144 = 59{\cdot}6$	
	$2{,}079 - \frac{2{,}079}{4} = 1{,}559 \times 0{\cdot}121 = 188{\cdot}6$	
	Indemnity .	385

This figure only differs from that (403·8) obtained with the full price by 4·6 per cent., which is negligible. The method advocated is therefore once again vindicated.

Any other possible change in the value of the units is merely a combination of the hypotheses considered above, and all possible cases can be classed under them.

Chapter II.—VALUES OF A FOREST AT ITS DIFFERENT AGES.

Capital values including soil and ensouchement.

51. Relative estimation is suitable for the valuation of the crop.—Valuation by positive estimation is the only correct method when the rate of interest for the sale value has to be ascertained; but it is no longer sufficient when the owner has no intention of parting with his property and the value of the damage effected by a fire which destroys the harvest is to be appraised. To compensate him, the value of the forest to the owner at its different ages must be known, this is the estimation in relation to the proprietor.

Assurance companies sometimes reason as follows :—

A coupe returns 500 francs in 25 years; at the age of 10 it is worth $\frac{500}{25} \times 10$. This is incorrect. The mere mean annual increment of a growing stock is not the co-efficient of the value of a coupe according to its age; it should rather be likened to an annuity which, added to itself every year together with compound interest, reproduces, at the end of the period of the rotation, a sum equal to the sale value of the exploitable coupe, including any intermediate yield. The actual value of the mean annual increment, therefore is less than the co-efficient in question. Conversely, the total value of the annual increments for the first m years is greater than m times the mean annual increment, for compound interest must be added. The calculation is made by relative estimation, the principles of which have been discussed in Section 38, and which we will now proceed to apply.

52. Values of a coppice-with-standards growing-stock, including the capital invested, or capital value at different ages.

Analysis of the exploitation.

Coppice with standards as detailed in section 44.

Capital invested	Soil	370		673 francs.
	Ensouchement			
	Charges capitalised	65		
	Standards: 120 new .	238		
	60 2nd-rotation			
	10 3rd do.			

Carried over . 673 francs.

	Brought forward		.	673 francs.
Yield	2nd-rotation . 3rd do. . 4th do. .	870		
	Coppice . .	250		1,120 „
	Capital value at 25 years		.	1,793

Net rate of interest

$$673\ (1 + x)^{25} = 673 \times 1{,}120$$

whence x = 4 per cent.

$$Cm = V\ \frac{(1 + t)^m}{(1 + t)^n - 1}$$

gives the value *to the owner* of the coppice-with-standards at its different ages. When m=0, as immediately after the final felling, it equals the capital invested, *i.e.*, the value of the soil with its *ensouchement* and the standards. The values of subsequent increments are added for the different ages.

When m = 1, the capital value at one year is :—

$$C^1 = 1{,}120\ \frac{1{\cdot}04^6}{(1{\cdot}04)^{25} - 1} = 1{,}120 \times \overset{\text{(iii)}}{0{\cdot}6005} \times \overset{\text{(i)}}{1{\cdot}04} = 700 \text{ francs.}$$

with m = 6, the capital value at 6 years becomes :—

$$C^6 = 1{,}120\ \frac{1{\cdot}04^6}{(1{\cdot}04)^{25} - 1} = 1{,}120 \times \overset{\text{(iii)}}{0{\cdot}6005} \times \overset{\text{(i)}}{1{\cdot}265} = 851 \text{ francs.}$$

with m = n, in addition to the soil value we have that of the crop ready for felling. The capital value at 25 years attains the maximum :—

$$C^{25} = 1{,}120\ \frac{1{\cdot}04^{25}}{(1{\cdot}04)^{25} - 1} = 1{,}120 \times \overset{\text{(iii)}}{0{\cdot}6005} \times \overset{\text{(i)}}{2{\cdot}6658} = 1{,}793 \text{ francs.}$$

When n = 1, the crops are annual, that is to say, in the rotation of 25 years there are 25 fellings each realising 1,120 francs. The formula is then reduced to :—$C = V\ \frac{1}{t}$ and the value would be

$$C = 1{,}120 \times \overset{\text{(iii)}}{25} = 28{,}000 \text{ francs.}$$

53. Definition of terms :—

"*Soil-value*" must not be confused with "*capital invested*" as is often done. "*Growing-stock*" must be distinguished from "*yield*," the two are identical only in the case

of simple coppice. As for the *capital invested*, from the point of view of the owner not disposed to sell the estate, it remains constant at all ages. It comprises the values of the soil, the root-stocks, the seedlings and the constant reserve of standards after the final felling. The capital invested in relative estimation *erga dominum* does not increase with age; the increment appertains to the yield; the final felling will remove this increment in the form of the yield and will re-establish the original proportions.

54. Capital values of a growing high-forest.—We will now examine the most complicated case, that of the high-forest wood of section 47, which is worked under a rotation of 140 years, with regeneration felling and intermediate thinnings at the age i.

At first, let us suppose that the seeding felling at 140 years yielding 2,000 francs, the secondary felling of 3,000 francs at 145 years, and the final felling of 3,000 francs at 150 years, are replaced by a single felling yielding 6,995 francs.

The observations on the value of the mean annual increment in Section 51 apply with greater force in the case of high-forest, owing to the length of the rotation and the capital locked up in the accumulated material. According to the conclusions arrived at in Sections 48 and 51, the following formula must be applied:

$$C = V \frac{(1 + t)^{n - i + m}}{(1 + t)^n - 1}$$

Immediately after the final felling m = 0 and the forest is in its original condition. The value of the capital invested, that is, the value of the soil together with that of the *ensouchement*, the seedlings and the saplings left over, is as follows:—

$$F = \frac{1{\cdot}025^{140-40}}{1{\cdot}025^{140} - 1} + 120\,\frac{1{\cdot}025^{140-60}}{1{\cdot}025^{140} - 1} + 250\,\frac{1{\cdot}025^{140-80}}{1{\cdot}025^{140} - 1} +$$

$$600\,\frac{1{\cdot}025^{140-100}}{1{\cdot}025^{140} - 1} + 800\,\frac{1{\cdot}025^{140-120}}{1{\cdot}025^{140} - 1} + 6{,}995\,\frac{1}{1{\cdot}025^{140} - 1} = 410 \text{ francs.}$$

If m = 0, immediately before the final felling, the value of the latter is added:—

$$6{,}995\,\frac{1{\cdot}025^{140}}{1{\cdot}025^{140} - 1} = 6{,}995 \times \overset{(i)}{31{\cdot}721} \times \overset{(iii)}{0{\cdot}03255} = 7{,}222 \text{ francs.}$$

The capital value of the whole estate is 7,405 francs.

When m = 1 the capital value at one year is :—

$$C^1 = \frac{60(1{\cdot}025)^{140-40+1} + 120(1{\cdot}025)^{140-60+1} + 250(1{\cdot}025)^{140-80+1}}{1{\cdot}025^{140} - 1}$$

$$\frac{+ 600(1{\cdot}025)^{140-100+1} + 800(1{\cdot}025)^{140-120+1} + 6{,}995(1{\cdot}025)^1}{1{\cdot}025^{140} - 1}$$

or

		(i)		
60	×	12·109	=	726·6
120	×	7·39	=	886·8
250	×	4·51	=	1,127·5
600	×	2·752	=	1,651·2
800	×	1·68	=	1,314·0
6,995	×	1·025	=	7,169·9

12,906 × 0·03255 (iii) = 420 francs.

With m = 10, the co-efficients of the fractions become :—

140 − 40 + 10 = 110; 140 − 60 + 10 = 90...70...50...30...10

and the capital value is :—

		(i)		
60	×	15·123	=	907·4
120	×	9·229	=	1,107·4
250	×	5·632	=	1,408·0
600	×	3·437	=	2,062·2
800	×	2·093	=	1,678·4
6,995	×	1·28	=	8,953·6

16,117 × 0·03255 (iii) = 525 francs.

When m = 40 and a fire destroys the forest *before* the removal of the material of the first thinning, the capital value of the coupe is :—

$$C^{40} = 60\,\frac{1{\cdot}025^{140}}{1{\cdot}025^{140} - 1} = 60 + \overset{\text{(i)}}{31{\cdot}721} \times \overset{\text{(iii)}}{0{\cdot}03255}$$

The co-efficients of the remaining numerators are :—

140 − 60 + 40 = 120; 140 − 80 + 40 = 100...80...60...40

and the capital value at 40 years is :—

		(i)		
60	×	31·721	=	1,903·2
120	×	19·358	=	2,322·9
250	×	11·814	=	2,953·5
600	×	7·21	=	4,326·0
800	×	4·4	=	3,520·0
6,995	×	2·685	=	18,781·4

33,807 × 0·03255 (iii) = 1,100 francs.

At age 40, if the first thinning has already been harvested at the time the fire breaks out, the calculation is modified to :—

$$C^{40} = 60 \frac{1{\cdot}025^{140}}{1{\cdot}025^{140}-1} - 60 \text{ or } 60 \frac{1}{1{\cdot}025^{140}-1} = 60 \times 0{\cdot}03255. \quad \text{(iii)}$$

The other terms remain as before and the capital value is reduced to 1,040 francs.

When m=50, the first thinning has been made, i will not recur till the next rotation and the length of the rotation must be added to its age. The capital value of the first thinning is then :—

$$60 \frac{1{\cdot}025^{140-(40+140)+50}}{1{\cdot}025^{140}-1}$$

This is simplified by considering n = 0, when the thinning has already been effected, and we have :—

$$60 \frac{1{\cdot}025^{0-40+50}}{1{\cdot}025^{140}-1} \text{ or } 60 \frac{1{\cdot}025^{50-40}}{1{\cdot}025^{140}-1}$$

The power of the other terms are 130, 110, 90, 70 and 50 and the capital value becomes 1,332 francs ; and so forth, the formula always remaining :—

$$C = V \frac{(1+t)^{n-i+m}}{(1+t)^{n}-1} \text{ with } t = \text{the rate of interest.}$$

Values of growing woods or yields alone.

55. Values of yield only at different ages of a growing wood without intermediate yield (coppice).—To ascertain the value of the yield alone all that is necessary is to deduct the value of the capital invested from the capital value.

Taking the example in Section 52 of a coppice-with-standards wood :—

Revenue or yield at age	1	=	700	— 673	=	27	francs.
Ditto ditto	6	=	851	— 673	=	178	„
Ditto ditto	25	=	1,793	— 673	=	1,120	„

When there are no intermediate fellings and the exploitation comprises a single periodical revenue, the intermediate yield is obtained more simply by multiplying the

capital invested by the accumulated interest for the period under consideration :—

							(i)			
This at age of	1	=	673	×	0·04	=	27	francs.
Ditto	6	=	673	×	0·265	=	178	„
Ditto	25	=	673	×	1·6656	=	1,120	„

Neglect of final decimals may cause slight differences, but these are invariably insignificant.

56. Value of yield only of a growing wood with thinnings (high-forest).—There are several methods and in view of the importance of the subject it is here dealt with in some detail.

Example.—The high-forest described in Section 47.

1st method (*inaccurate*).—The interest derived from the capital (410) invested for m years is :—

				(i)			
After 1 year	:	410	×	0·025	=	10	francs.
10	:	410	×	0·28	=	115	„
40	:	410	×	1·685	=	690	„
50	:	410	×	2·437	=	1,000	„

2nd method (*inaccurate*).—The capital capable of producing 12,591 francs every 140 years is considered to be put out at interest for m years and the capital invested is deducted :—

				(iii)		(i)					
After 1 year	:	12,591	×	0·03255	×	1·025	—	410	=	10	francs.
10	:	12,591	×	0·03255	×	1·28	—	410	=	115	„
40	:	12,591	×	0·03255	×	2·685	—	410	=	690	„
50	:	12,591	×	0·03255	×	3·437	—	410	=	1,000	„

3rd method (*inaccurate*).—Or more simply : What is the accumulated interest in m years of a capital yielding 12,591 francs every 140 years ?

After 1 year	:	12,591	×	0·03255	×	0·025	=	10	francs.
10	:	12,591	×	0·03255	×	0·28	=	115	„
40	:	12,591	×	0·03255	×	1·685	=	690	„
50	:	12,591	×	0·03255	×	2·437	=	1,000	„

4th method (*legitimate and accurate*).—The capital is deducted from the capital value obtained in Section 54 by the application of the formula—

$$C = V \frac{(1 + t)^{n - 1 + m}}{(1 + t)^{n} - 1}$$

Immediately before the final felling: 7,405 — 410 = 6,995 francs.
Immediately after the final felling: 410 — 410 = 0.

A priori these results were obvious:—

After 1 year:	420	—	410	=	10	francs.
10 :	525	—	410	=	115	„
40 before, the thinning	1,100	—	410	=	690	„
40 after, the thinning	1,040	—	410	=	630	„

The proof lies in the difference between the last two items:—

690—630=60 francs, which is the value of the first thinning.

Up to this point the values obtained by all four methods are the same, but at 50 years we get 1,332—410=922 francs.

Here we find a divergence which will go on increasing up to the end of the rotation. The reason for this is that the first three methods are based on the *average* of the several sales and are therefore inaccurate when intermediate fellings come into question. On the other hand, the last method follows the abrupt variations arising at the ages of 40, 60, 80, 100 and 120 years when the thinnings add at a single step a definite sum, followed by 20 years' stagnation.

The grouping of the regeneration fellings into a single operation yielding 6,995, for the sake of convenience, is not accurate as it does not reflect the oscillations of the first ten years, and does not take into account the considerable accumulation of valuable material standing in the forest during that period. Consequently, the *nil* value shown immediately after the felling at 140 years and that of 10 francs at the age of 10 are equally false. For the capitalised sum 6,995 must be substituted the sale prices at the time they fall due, *viz.*, 2,000 francs at 140 years, 3,000 francs at 145 years (or 5 years in the new rotation), and 3,000 francs at 150 years (or 10 years). All the terms of the formula, without exception, must be developed.

Let us now complete the discounting without omission or displacement. The denominator, $1{\cdot}025^{140}-1$, remains constant in all the fractions at all ages; it will be found in Table III. All the numerators are $1{\cdot}025^{x}$; after each felling they become 1; it is the power x alone that varies.

The following table renders their development easy to follow, though apparently somewhat complicated:—

Co-efficients relating to the high forest of Section 47.

Ages.	1st thinning @ 40 years.	2nd thinning @ 60 years.	3rd thinning @ 80 years.	4th thinning @ 100 years.	5th thinning @ 120 years.	Seeding felling @ 140 years.	Secondary felling @ 145 years.	Final felling @ 150 years.
1 year	140−40+1 =101	140−60+1 =81	140−80+1 =61	140−100+ 1=41	140−120+ 1=21	140−140+ 1=1 or 0 −0+1	140−145+ 141=136	140−150+ 141=131
5 years (before the secondary felling) . .	140−40+5 =105	140−60+5 =85	140−80+5 =65	140−100+ 5=45	140−120+ 5=25	140−140+ 5=5 or 0 −0+5	140−145+ 145=140	140−150+ 145=135
5 years (after the secondary felling) . .	105	85	65	45	25	5	”	135
10 years (before the final felling) . . .	140−40+10 =110	140−60+10 =90	140−80+ 10=70	140−100+ 10=50	140−120+ 10=30	140−140+ 10=10 or 0−0+10	140−145+ 10=5 or 0−5+10	140−150+ 150=140
10 years (after the final felling)	110	90	70	50	30	10	5	”
20 years	120	100	80	60	40	20	15	10
30 years	130	110	90	70	50	30	25	20
40 years (before the thinning)	140−40×40 =140	120	100	80	60	40	35	30
40 years (after the thinning)	”	120	100	80	60	40	35	30
50 years	140−(40+ 140)+50 or 0−40 +50=10	130	110	90	70	50	45	40
60 years (before the thinning)	60−40=20	140	120	100	80	60	55	50
60 years (after the thinning)	20	140	120	100	80	60	55	50
70 years	70−40=30	140−(60+ 140) +70 or 70−60 =10	130	110	90	70	65	60
80 years (before the thinning) . . .	40	20	140	120	100	80	75	70
140 years (before the seeding felling) . .	140−40=100	80	60	40	20	140−140+ 140=140	140−145+ 140=135	140−150+ 140=130
140 years (after the seeding felling) . . .	100	80	60	40	20	”	135	130

The yield at age m is :—

$$S^m = \frac{V^I(1+t)^{n-i^I+m} + V^{II}(1+t)^{n-i^{II}+m} + V^{III}(1+t)^{n-i^{III}+m} + \ldots}{(1+t)^n - 1} - F$$

The results of the calculations are indicated further on.

5th method (approximate)—

In section 38 we saw that: $C = F + S$

whence: $S = C - F$

or $$F = V \frac{1}{(1+t)^n - 1}$$

and $$C = V \frac{(1+t)^n}{(1+t)^n - 1}$$

From which it would seem that we can evolve

$$S^m = V \frac{(1+t)^{n-i+m}}{(1+t)^n - 1} - V \frac{1}{(1+t)^n - 1} = V \frac{(1+t)^{n-i+m} - 1}{(1+t)^n - 1}$$

that is to say, that the two expressions for S^m should give the same result. This, however, is not the case; all the figures furnished by the 4th method before each thinning are inferior by 90 francs to those of the 5th method obtained by the formula :—

$$E = \frac{V^I\left[(1+t)^{n-i^I+m} - 1\right] + V^{II}\left[(1+t)^{n-i^{II}+m} - 1\right]}{(1+t)^n - 1}$$

$$\frac{+ V^{III}\left[(1+t)^{n-i^{III}+m} - 1\right] + \ldots}{(1+t)^n - 1}$$

Moreover, the difference between the values immediately before and after each thinning should represent the value of the thinning; this is the case in the fourth method but not with the fifth.

It is the latter which errs in having substituted for F the formula $V \frac{1}{(1+t)^n - 1}$. But here V is merely the aggregate of the yield of the several coupes: $V = V^{I} + V^{II} + V^{III} + \ldots$, whereas what is required is their values capitalised at compound interest to the end of the rotation, *i.e.* :—

$$V = V^{I} (1+t)^{n-i'} + V^{II} (1+t)^{n-i''} + - - -$$

In the particular case of the forest described in Section 47, the difference between the simple aggregate and its capitalisation is 80 francs, as may be verified by reference to the tabular statement below.

The fifth formula should therefore be amended as follows:—

$$S_m = \frac{[V^{I}(1+t)^{n-i'+m} - (1+t)^{n-i'}] + V^{II}[(1+t)^{n-i''+m} - (1+t)^{n-i''}] + \ldots}{(1+t)^n - 1}$$

This process, however, is clumsy; minus as well as plus quantities appear. It is much simpler to take only the first term of each factor and then subtract F, the invested capital; which is precisely the fourth method. The resultants of the first three methods can also be corrected by simply deducting the capitalised yields of the thinnings. But even this indirect process is inferior to the fourth method.

A comparison of the totals furnished by these diverse methods indicates the importance of a selection.

Values of the harvests (growing woods) on one hectare of high-forest under a rotation of 140 years, under the conditions detailed in Section 47.

Ages.	1st, 2nd and 3rd methods identical and inaccurate.	4th Method. The seeding fellings discounted for 140 years, inaccurate.	4th Method. Legitimate and accurate. $\frac{V^1(1+t)^{n-i^1+m}+..}{(1+t)^n-1}-F$	5th Method. Approximate. $\frac{V^1(1+t)^{n-i^1+m}-1+...}{(1+t)^n-1}$
	Francs.	Francs.	Francs.	Francs.
1 year	10	133	5,130	5,220
5 years (before the secondary felling)	54	176	5,705	5,795
5 years (after the secondary felling)	„	„	2,705	2,893
10 years (before the final felling)	115	237	3,115	3,205
10 years (after the final felling)	„	„	115	303
20 years	262	385	262	352
30 years	449	573	449	539
40 years (before the thinning)	690	813	690	780
40 years (after the thinning)	630	755	630	722
50 years	1,000	1,045	922	1,012
60 years (before the thinning)	1,394	1,418	1,295	1,385
60 years (after the thinning)	1,274	1.302	1,175	1,269
70 years	1,898	1,741	1,619	1,709
80 years (before the thinning)	2,546	2,307	2,187	2,277
80 years (after the thinning)	2,296	2,068	1,937	2,035
90 years	3,374	2,717	2,594	2,684
100 years (before the thinning)	4,432	3,559	3,436	3,526
100 years (after the thinning)	3,832	2,978	2,836	2,946
110 years	5,790	3,863	3,745	3,835
120 years (before the thinning)	7,528	5,032	4,909	4,999
120 years (after the thinning)	6,728	4,258	4,109	4,225
130 years	9,750	5,497	5,374	5,464
140 years (before the seeding felling)	12,595	7,117	6,995	7,085
140 years (after the seeding felling)	5,600	350	4,995	5,150

These results can be illustrated by graphic curves, the verticals giving the age and the horizontals the corresponding values of the forest. For the first few years all the curves are nearly coincident. But immediately after the harvest of the important thinnings the curves of the first three methods diverge from those of the other two and continue to rise regularly to the climax of 12,591 francs for the broad-leaved high forest of Section 47, or 5,180 francs for the pine forest of Section 46. In short, they cannot be relied on for an accurate valuation where intermediate yields are realised.

The curve of the fifth method rises rapidly above that of the fourth and then continues on an approximately parallel course, reflecting its abrupt mutations engendered by the thinnings. In no case, however, should the even line of the first three methods be surmounted; nevertheless, when the intermediate yields are not considerable, the curve of the fifth method does actually transgress, which proves its inaccuracy. Calculations bear out this fact as they reveal an excess of 90 or 88 fr., according to the type considered, at each thinning.

This subtle question will be made clearer if we study several examples. Let us take the pine forest described in Section 46. The tabular statement on page 104 gives the details of the co-efficients obtained from the general formula:—

$$V \cdot \frac{(1+t)^{n-i+m}}{(1+t)^{n}-1}$$

What is the yield at 44 years immediately before the fifth thinning?

1st method (*inaccurate*).—The yield at 44 years is equivalent to the proceeds of the capital invested (293) through its interest accumulated for 44 years:—

$$\text{(i)}$$
$$293 \times 7{\cdot}5572 = 2214{\cdot}3 \text{ francs.}$$

Co-efficients of fractions relating to the thinnings in the pine forest described in Section 46.

Ages.	1st thinning at 12 years.	2nd thinning at 20 years.	3rd thinning at 28 years.	4th thinning at 36 years.	5th thinning at 44 years.	6th thinning at 52 years.	Final felling at 60 years.
1 year . . .	60—12+1=49	60—20+1=41	60—28+1=33	60—36+1=25	60—44+1=17	60—52+1=9	60—60+1=1
12 years (before the thinning).	60—12+12=60	60—20+12=52	60—28+12=44	60—36+12=36	60—44+12=28	80—52+12=20	60—60+12=12
12 years (after the thinning).	"	52	44	36	28	20	12
20 years (before the thinning).	20—12=8	60—20+20=60	52	44	36	28	20
20 years (after the thinning).	8	"	52	44	36	28	20
28 years (before the thinning).	28—12=16	28—20=8	60	52	44	36	28
28 years (after the thinning)	16	8	"	52	44	36	28
36 years (before the thinning).	36—12=24	16	36—28=8	60	52	44	36
36 years (after the thinning).	24	16	8	"	52	44	36
44 years (before the thinning).	44—12=32	24	16	8	60	52	44
44 years (after the thinning).	32	24	16	8	"	52	44
52 years (before the thinning).	52—12=40	32	24	16	8	60	52
52 years (after the thinning).	40	32	24	16	8	"	52
60 years (before the final felling).	60—12=48	40	32	24	16	8	60
60 years (after the final felling).	48	40	32	24	16	8	"

2nd method (inaccurate).—The capital capable of yielding 5,180 francs every 60 years is put out at interest for 44 years, and from the resultant the invested capital of the forest is deducted :—

$$5{,}180 \times \overset{\text{(iii)}}{0{\cdot}05656} \times \overset{\text{(i)}}{8{\cdot}5572} - 2{,}93 = 2{,}214{\cdot}30 \text{ francs.}$$

3rd method (inaccurate).—At 44 years the interest on the capital yielding 5,180 francs every 60 years is :—

$$5{,}180 \times \overset{\text{(iii)}}{0{\cdot}05656} \times (\overset{\text{(i)}}{8{\cdot}5572} - 1) = 2214{\cdot}30 \text{ francs.}$$

These results are erroneous as they do not take into account the five thinnings which were carried out prior to the fire. To correct them the capitalised values of the thinnings from the dates of realisation up to the date of the fire, at 5 per cent., must be deducted.

From 2,214·30

deduct $4 \times 1{\cdot}05^{32} + 8 \times 1{\cdot}05^{24} + 35 \times 1{\cdot}05^{16} + 175 \times 1{\cdot}05^{8}$

		(i)			
4	×	4·765	=	19·1	
8	×	3·225	=	25·8	379·80
35	×	2·183	=	76·4	
175	×	1·477	=	258·5	

Value of the growing wood . . 1,834·50 francs.

4th method (legitimate and accurate)—

$$S\ 44 = \frac{4 \times 1{\cdot}05^{32} + 8 \times 1{\cdot}05^{24} + 35 \times 1{\cdot}05^{16} + 175 \times 1{\cdot}05^{8}}{1{\cdot}05^{60} - 1}$$
$$+ \frac{552 \times 1{\cdot}05^{60} + 625 \times 1{\cdot}05^{52} + 2{,}223 \times 1{\cdot}05^{44}}{1{\cdot}05^{60} - 1} - 293$$

		(i)		
4	×	4·765	=	19·1
8	×	3·225	=	25·8
35	×	2·183	=	76·4
175	×	1·477	=	258·5
552	×	18·679	=	10,310·8
625	×	12·643	=	7,901·9
(2333—110)	×	8·557	=	19,022·2

$$37{,}614{\cdot}7 \times \overset{\text{(iii)}}{0{\cdot}05656} = 2{,}127{\cdot}5$$
$$-\ 293$$

1,834·5

5th method (approximate)—

$$V\frac{(1+t)^{n-i+m}-1}{(1+t)^{n}-1}$$

$$\frac{4(1{\cdot}05^{32}-1)+8(1{\cdot}05^{24}-1)+35(1{\cdot}05^{16}-1)+175(1{\cdot}05^{8}-1)}{1{\cdot}05^{60}-1}$$

$$+\frac{552(1{\cdot}05^{60}-1)+625(1{\cdot}05^{52}-1)+2{,}223(1{\cdot}05^{44}-1)}{1{\cdot}05^{60}-1}$$

		(i)		
4	×	3·765	=	15·1
8	×	2·225	=	17·8
35	×	1·183	=	41·4
175	×	0·477	=	83·5
552	×	17·679	=	9,758·8
625	×	11·643	=	7,276·9
(2333 − 110)	×	7·557	=	16,799·2

(iii)
33,992·7 × 0·05656 = 1,922·60

Comparing this method with the fourth, we see that in the latter F., *i.e.* 293, is actually deducted, whereas here we only deduct—

$$\frac{4+8+35+175+552+625+2{,}223}{1{\cdot}05^{60}-1}=\frac{3{,}622}{17{\cdot}679}=205 \text{ francs.}$$

Consequently, the fifth method invariably arrives at an excess of 293—205=88 francs before each thinning, as can be seen from the figures of the appended table.

The modification required for its correction may be expressed in the following formula:—

$$\frac{4(1{\cdot}05^{32}-1{\cdot}05^{48})+8(1{\cdot}05^{24}-1{\cdot}05^{40})+35(1{\cdot}05^{16}-1{\cdot}05^{32})}{1{\cdot}05^{60}-1}$$

$$+\frac{\ldots\ldots\ldots+2{,}223(1{\cdot}05^{44}-1)}{1{\cdot}05^{60}-1}$$

$$=\frac{-22{\cdot}5-30{\cdot}5-90{\cdot}4-305{\cdot}9+9{,}105{\cdot}8+6{,}978{\cdot}7+16{,}799{\cdot}3}{17{\cdot}679}$$

$$=\frac{32{,}434{\cdot}5}{17{\cdot}679}=1{,}834{\cdot}50 \text{ francs.}$$

Summary of the several methods.

Values of the yields (growing woods) per acre of a pine forest under a rotation of 60 years, under the conditions described in Section 46.

Ages.	1st, 2nd and 3rd methods: identical and inaccurate.	4th Method : legitimate and accurate $\frac{V(1+t)^{n-i+m}+\ldots}{(1+t)^n-1}-F=$	5th Method : approximate. $\frac{V[(1+t)^{n-i+m}-1]+\ldots}{(1+t)^n-1}$
	Francs.	Francs.	Francs.
12 years (before the thinning).	233	233	321
12 years (after the thinning).	"	229	317
20 years (before the thinning).	484	479	567
20 years (after the thinning).	"	471	559
28 years (before the thinning).	856	836	924
28 years (after the thinning).	"	801	891
36 years (before the thinning).	1,404	1,323	1,411
36 years (after the thinning).	"	1,148	1,246
44 years (before the thinning).	2,214	1,834	1,922
44 years (after the thinning).	"	1,282	1,402
52 years (before the thinning).	3,411	2,067	2,155
52 years (after the thinning).	"	1,442	1,568
60 years (before final felling).	5,180	2,223	2,311
60 years (after final felling)	"	"	214

All the totals are reducible to the same amount if the 1st, 2nd, 3rd and 5th methods are suitably modified. The fourth is, however, the simplest and entails the least danger of errors, material or in reasoning, and is therefore the one to be recommended.

Values of growing-stocks.

57. Value of growing-stock in high-forest.—As it is the growing-stock that is destroyed by the fire, it will be of interest to enquire into the method of calculating its value. All that is required is to add the value of seedlings and

reserved trees to the value of the yield. In the case contemplated in Section 47 and the table on page 102 it would be :—

Value of growing stock at one year	.	250 + 5,130 = 5,380 francs.
" " " 30 years	.	250 + 449 = 699 "

58. Value of growing-stock in coppice-with-standards.—Taking the wood discussed in Section 44, we add the value of the standards reserved, 238, to the values calculated in Section 55.

Value of growing-stock at one year	27 + 238 =	265 francs.
" " " 25 years	1,120 + 238 =	1,358 "

Relative estimation with rate of interest obtained by positive estimation.

59. To value a forest at its different ages, the real rate of interest, ascertained by positive estimation, is applied by the system of relative estimation.

Arguments.—The first step in calculating the values of a forest at its different ages is to analyse the constituent elements of the exploitation, capital invested (soil, material) and revenue. Then the forest is estimated at the end of the rotation by the positive method and the true rate of interest is ascertained. With the true rate thus established, that is to say, with a sound foundation, the values at all ages can be obtained by relative estimation. The sequence of the operations is summed up as follows :—

1st step.—Calculation of the true rate of interest by positive estimation.

2nd step.—This rate is interpolated into the formula of relative estimation.

60. Formulæ applicable to the several elements and ages of forests :—

$$C = V \frac{(1+t)^{n-i+m}}{(1+t)^n - 1}$$

is of general application.

V is the periodic principal yield; the sole return in a simple coppice.

Exploitation with a single periodic felling.

In a simple coppice $n = i$

The capital invested is :—

$$F = V \frac{1}{(1+t)^n - 1}$$

at m years the increment amounts to—

$$V\frac{(1+t)^m-1}{(1+t)^n-1}$$

The total capital value (capital invested plus increment).

$$C=V\frac{(1+t)^m}{(1+t)^n-1}$$

Exploitations with intermediate fellings.

With intermediate fellings the value of each : V′ V″ V‴ must be added to that of the principal felling.

$$\text{Capital}=V\frac{1}{(1+t)^n-1}+V'\frac{(1+t)^{n-i'}}{(1+t)^n-1}+V''\frac{(1+t)^{n-i''}}{(1+t)^n-1}+\ldots$$

With m less than i′, the total capital value is :—

$$C=V\frac{(1+t)^m}{(1+t)^n-1}+V'\frac{(1+t)^{n-i'+m}}{(1+t)^n-1}\times V''\frac{(1+t)^{n-i''+m}}{(1+t)^n-1}+\ldots$$

When m=i′, before the felling :—

$$C=V\frac{(1+t)^m}{(1+t)^n-1}+V'\frac{1}{(1+t)^n-1}+V''\frac{(1+t)^{n-i''+m}}{(1+t)^n-1}+\ldots$$

When m is greater than i′ :—

$$C=V\frac{(1+t)^m}{(1+t)^n-1}+V'\frac{(1+t)^{m-i'}}{(1+t)^n-1}+V''\frac{(1+t)^{n-i''+m}}{(1+t)^n-1}+\ldots$$

The total yield equals these capital values less the invested capital, for instance when m is greater than i′ :—

$$S=V\frac{(1+t)^m}{(1+t)^n-1}+V'\frac{(1+t)^{m-i'}}{(1+t)^n-1}+V''\frac{(1+t)^{n-i''+m}}{(1+t)^n-1}+\ldots-F.$$

61. Advantages of this method.—The method of *relative estimation with the true rate of interest obtained by positive estimation*, is very simple as it makes use of but one formula.

It is as accurate as can be expected in matters pertaining to sylviculture. The values for the soil and exploitable material, as well as the initial and final values, *i.e.*, before and after felling, obtained by this method are the same as those resulting from the "direct estimation of timber merchants."

The values attributed are those which the property and produce have for the owner, thus avoiding the polemics of the ocular valuation of growing woods.

The direct valuation *in situ* is limited to the minimum of objects and the appraisement of these, if not always easy, is at least invariably possible.

Woods are treated as a capital constantly increasing by the addition of its compound interest, which is not perhaps

altogether correct. "The annual production is not constant nor the rate of value increment. Obedient to laws, the influence of which cannot be exactly gauged, they both vary with the fertility of the soil, the species, the system of treatment, the age, the consistence of the growing-stock, etc." The processes of vegetation are unknown; no one can assert that they follow the same mathematical rule as the rental, or if they do, it is conditional on the latter being composed of varying rates which decrease as the rotation lengthens. However, the divergence is small and these physiological arguments are sounder in theory than in practice. The one really important factor is the mean of all the rates applicable to the forest from its origin. It is the curve of compound interest that, within moderately wide extremes, appears to approach most closely to the actual values depending on the vagaries of vegetable development. M. Hüffel admits—" the analogy between a growing forest and capital placed at compound interest. In pure finance, it is true, the rate is immutable, whereas it varies in the forest. However, a mean rate can be admitted, sufficiently constant when the rotation is not too long, in which case the guiding laws are identical."

At all events, in case of injury, the difference, if any, is slight.

The question involved is reparation for the injury done. No human power can bring the burnt forest back to life. There remains but one way of doing justice to the owner, and that is by granting him a money indemnity sufficient to enable him to draw an income equal to that he would have obtained from his forest, at the same rate of interest. It is, therefore, pre-eminently a question of compound interest.

Devarenne expresses the opinion: "The evolution of woody growth approximates closely with the law of development of compound interest." Mr. Détrie does not think that any other rule is applicable.

Mr. Reuss subscribes to the same theory: "if it is desired to thoroughly analyse the theory of rental, determine the value of every growing stock, investigate the lines on which the value of timber increases in the living tree, one is compelled to resort to the convention of compound interest and to introduce it into that of ground rent." Finally, Mr. Puton, who has studied the subject most deeply, has also adopted it. Reinforced by such authority and by its excellent results, it requires no further plea for its acceptance.

PART III.

APPRAISEMENT OF DAMAGE.

I

Fire in simple coppice.

Estimation without disorganisation of management.

62. By direct ocular estimation of all kinds of woods; approximate.—The simplest case is that of a moderately productive spinney, treated as coppice. There is no definite management but local custom prescribes felling every 25 years. The yield per hectare is 95 *stères* of charcoal wood, 30 *stères* of billets and 500 faggots. The market value is :—

95 *stères* at	2 = 190	}	
30 „ at	6 = 180	}	400 francs.
500 faggot at 6 per 100	= 30	}	

First method—approximate.—The growth over the whole area is destroyed by the fire at the age of 6 years.

1. *Value of growing stock.*—The material burnt consisted of 200 faggots of twigs at 5 francs per 100 .	10 francs.
There being no working plan there is no disorganisation of management; there is also no depreciation of wood as the owner is not obliged to cut over at 25 − 6 = 19 years, at which age the exploitable material is of little value, he will rather postpone the felling for 6 years and continue with the rotation at 25 years.	
2. *Cutting back.*—The coppice must be cut back at once, the cost of this operation will be 3 days woodcutters' wages at 3 francs	= 9 „
Loss	. 19 francs.
3. *Salvage.*—The sale prices of the twigs cut back must be deducted, say	4 francs.
Total damage	. 15 francs.

This method is open to criticism.

I. Had the fire not taken place the owner would have

realised 400 francs 19 years later; whereas, owing to the throwback of 6 years, he will only have:—

1. That sum discounted for 6 years, say, at 3 per cent.
$400 \times \underset{\text{(ii)}}{0{\cdot}8375}$ . . . . . . = 335
2. Of the indemnity collected there remains after the expenditure on cutting back, but 10 francs. This sum at compound interest for 19 years will become $10 \times \underset{\text{(i)}}{1{\cdot}753}$ = 17·53

Total . 352·53

The indemnification for the detriment caused is therefore insufficient.

II. Ocular estimation of immature woods is defective in principle as well as in practice. This the next section will demonstrate as well as indicate the corrective.

63. Difficulty of ocular estimation of immature woods. Calculation of value of growing woods.—It is rare that coupes are felled at much earlier ages than is usually prescribed in working plans and, therefore, it is difficult to fix a value for very young woods no portion of the produce of which has reached a saleable condition. In such cases, when a fire has destroyed the growth the estimation must be made mathematically to avoid an ocular valuation. Not only is a detailed examination on the ground avoided but the valuation becomes more accurate. Indeed, the increment of the first few years is of little or no value and does not cover the cost of extraction. It is only from about the tenth year, according to the species, soil and climate, that the growing stock begins to repay exploitation.

In the preceding example the valuation of the 200 faggots at 10 francs is arbitrary and open to objection and that of the sale of the salvage at 4 francs is optimistic; actually there would be no sale at all for twigs of 6 years of age, the owner would probably have to give them away, or still more probably to leave them to rot *in situ*; consequently, it would be better not to take these values into account at all. Such considerations cause the first method to be deemed approximate.

As in questions of finance, when an owner has been exposed to loss it is right, if not obligatory, to be strict and to overlook nothing. From a legal standpoint it is not the present saleable value (*nil* or negligible) of a young crop that should be adopted but its *potential or future value*; for,

though in burning shoots of from 1 to 10 years the fire probably has not destroyed any marketable material, yet it has made away with that which would have attained value in due course. It is not only in its last years that a forest acquires pecuniary value, it has gradually grown to that stage from its origin by a progression which may be compared with that of compound interest.

We have seen in Sections 38 and 57 that the total increment of m years, otherwise the growing stock at m years, is represented by :—

$$V \frac{(1 + t)^m - 1}{(1 + t)^n - 1}$$

The injury caused to the coupe which, instead of being felled over at n years, is worked actually at n—m years is expressed by :—

$$V \frac{(1 + t)^n - (1 + t)^{n-m}}{(1 + t)^n - 1} \times \frac{1}{(1 + t)^{n-m}}$$

The two formulæ, though apparently differing, are actually identical as can be shown by writing them :—

$$V \left\{ \frac{1}{(1 + t)^n - 1} \quad [(1 + t)^m - 1] \right\}$$

$$\text{and } V \left\{ \frac{1}{(1 + t)^n - 1} \left[\frac{(1 + t)^n - (1 + t)^{n-m}}{(1 + t)^{n-m}} \right] \right\}$$

$$\text{Now } \frac{(1 + t)^n - (1 + t)^{n-m}}{(1 + t)^{n-m}} = \frac{(1 + t)^n}{(1 + t)^{n-m}} - 1$$

$$= (1 + t)^{n-n+m} - 1 = (1 + t)^m - 1$$

So that the terms by which the two formulæ differ are identical.

Therefore, *to the owner who has no intention of selling the estate*, the value of the young re-growth destroyed at the time of the fire is equivalent to the difference between the value of the coupe exploited at the normal age of the rotation and its value at the earlier age of actual felling necessitated by the fire; which difference must be discounted to the date of the occurrence of the fire.

64. Legitimate method of estimation without disorganisation in management.—

Second method.—According to the formula of Section 38, $F = \frac{1}{(1 + t)^n - 1}$, the capital capable of producing 400 every 25 years at 3 per cent. is :

(iii)

$$400 \times 0{\cdot}9143 = 365{\cdot}72 \text{ francs.}$$

1. *Value of growing stock.*—This capital bears in 6 years (the age at the time of the fire) the following accumulated interest, according to table I.

$$x = F\,[\,(1 + t)^m - 1]$$

$$\overset{(i)}{365{\cdot}72\ (1{\cdot}194 - 1)} \qquad = 70{\cdot}95 \text{ francs.}$$

The figure 70·95 more truly represents the value of the growing-stock than the estimate: 200 faggots = 10 francs. The proposal to introduce into this calculation annuities, valuation of the annual production of leaf and a special tariff, is a superfluous complication. The foregoing calculation is in no way affected by these unnecessary details.

2. *Accessory expenditure. Cutting back.*—The cost of cutting back must be added: 3 days woodcutter's wages at 3 francs . . . . . . = 9·00 francs.

Loss . 79·95 francs.

3. *Salvage.*—Deduct sale price of shoots cut 4·00 francs.

Net loss proved and indemnity payable, . . 75·95 francs.

When the shoots burnt are unsaleable, the pecuniary indemnity to be paid by the responsible party will amount to the value of the growth destroyed together with the cost of cutting back. In our example 79·95 francs.

Verification of the method:—The cost of cutting back passes through the hands of the owner directly to the wood-cutters, consequently, the actual amount of compensation received by the owner is 70·95 francs.

Invested at compound interest for 19 years. This sum increases to $\overset{(i)}{70{\cdot}95 \times 1{\cdot}7535}$ . . . . . = 124·4 francs.

In 19 years the wood will have grown up again and will then be worth to the owner, still unwilling to sell the estate . . . $\overset{(i)}{365{\cdot}72 \times (1{\cdot}7535 - 1)}$ = 275·6 francs.

Total . 400 francs.

that is to say, the exact amount that would have been realised had the fire not occurred. This method is therefore correct.

Third method.—The problem may also be resolved by the formula of Sections 38 and 60, expressing the value of growing woods at the age m.

$$V\frac{(1+t)^m-1}{(1+t)^n-1}$$

Twenty-five years after the fire the owner will sell the coupe — V ; he ought however to have realised its value m years earlier. His loss is equal to the interest on this sum for m years, *i.e.*, V [$(1+t)^m - 1$], which will be repeated every n years. The amount of the compensation should therefore equal the capital capable of yielding that sum every n years.

$$V[(1+t)^m-1] \times \frac{1}{(1+t)^n-1}$$

This formula represents the value of a growing-stock at the age m ; it is calculated with the help of table III by dividing by one another the figures in the table corresponding to the ages n and m, and then multiplying the quotient by the value of the coupe at maturity. Applied to our example we obtain (table III) :

$$400\ \frac{(1+0{\cdot}03)^6-1}{(1+0{\cdot}03)^{25}-1} = 400\ \frac{0{\cdot}914}{5{\cdot}153} = 70{\cdot}95 \text{ francs.}$$

It is simpler still to multiply the factors in tables I and III corresponding to the ages n and m :—

400 (1·194 — 1) 0·9143	= 70·95 francs.
Add cost of cutting back	9
	79·95 francs.
Deduct.—Sale of shoots cut back . . .	4
Loss proved and compensation payable .	75·95 francs.

Both the latter methods agree and are the only ones that recommend themselves.

Estimation with disorganisation of management.

65. Circumstances liable to entail anticipation or postponement of the felling following on cutting back. —It is very rare that a whole forest is destroyed. Usually a fire extends over a single coupe or even a small portion of a coupe. Thereafter, when the coupe comes in rotation for

felling, there will be two alternatives: to fell prematurely the portion burnt over and cut back, or to exclude it from the working and postpone its exploitation till the next rotation.

The decision will depend upon the species, the age and the ruling prices of the locality. A growing-stock of soft-woods subject to early decay, or even of beech which loses its power of producing stool shoots at an early age, requires cutting back more promptly than, say, an oak wood.

If the fire took place shortly before the recurrence of the regular exploitation, the area cut back must not be felled over again at the regular date, but will be left over till the next rotation. On the other hand, when coppice is burnt in its early youth, to leave it to grow for 40 or 50 years would probably entail a heavier loss than its premature felling at the date prescribed by the working plan, though not the correct age.

Hesitation can only exist when the damage has taken place near the middle of the rotation. Each case must be settled on its own merits.

Example.—A coppice of superior species with a rotation of 25 years has been destroyed at 10 years of age. Its value at 15, 25 and 40 years are 130 francs, 400 francs and 960 francs, respectively. Should it be felled when 15 years old, that is to say, at the normal date prescribed by the working plan, or is it preferable to let it stand over till 40 years old, at the end of the rotation succeeding the current one?

There are three issues for examination:—

1. Cultural considerations: ages at which the species coppice well or ill.
2. Comparison of financial results of felling at 15, 52 and 40 years.
3. Amount of compensation payable according to decision as to age of felling: 15 or 40 years.

1. At 15 years of age all the species represented produce good coppice shoots. At 40 years, oak, the predominating and principal species, still produces a vigorous re-growth. From the general physiological standpoint, therefore, it is immaterial whether the exploitation is advanced or deferred.

If the re-growth contains useless shrubs and thorny growth the lengthening of the rotation will cause their death or at least their numbers and vitality will be decreased, to the gain of the rest of the growing-stock. Whereas, with

premature felling at the age of 15 they will be vexatiously favoured. With such a combination, therefore, the postponement of the exploitation is to be preferred.

2. The value of the coupe at 15 years (130 francs) put out at compound interest during the second rotation becomes $130 \times 2{\cdot}094 = 272{\cdot}20$ francs. Added to the value of the
(i)
coupe at the end of the second rotation (400 francs), the total amounts to 672·20 francs, which is far inferior to the yield of 960 francs at 40 years age. It would seem, therefore, that the interest of the owner will be better served by deferring the felling. These financial questions, however, are not his concern but that of the appraiser charged with determining the amount of compensation. Whatever the decision may be, the proprietor will receive the same sum, and that will be equal to the amount he would have realised normally had the fire not taken place, as will be seen later.

3. The indemnity will be inversely proportionate to the value of the coupes and will vary in the following manner:—

Felling at age of 15.—Instead of 400 francs only 130 will be realised. The prejudice is therefore to the extent of $400 - 130 = 270$ francs. As it refers, however, to a period 15 years hence, it must be discounted for that number of years

(ii)

$$270 \times 0{\cdot}642 = 173{\cdot}34 \text{ francs.}$$

No accessory charges, negative or positive, need be considered as they will be the same on both sides.

Felling at age of 40.—In 15 years normally 400 francs would have been realised, but actually there will be no yield at that date. This sum at compound interest for 25 years
(i)
would become $400 \times 2{\cdot}094 = 837{\cdot}60$ francs, to which would be added the value of a new coupe of 400 francs, or 1,237·60 francs in all. The deferred sale at 40 years yields 960 francs. The loss then amounts to $1237{\cdot}60 - 960 = 277{\cdot}60$ francs. This discounted for 40 years is:—

$$277{\cdot}6 \times 0{\cdot}30656 = 85{\cdot}10 \text{ francs.}$$

(ii)

The party responsible would have to pay, therefore, 85·10 francs, as against 173·34 francs in the case of the premature harvest.

But it is pertinent to enquire whether the author of the fire can compel the owner to wait 40 years if he does not wish

it? Such a contention appears untenable. It traverses the principle expounded by eminent economists (see Section 22) "the former conditions must be re-established as soon as possible even though greater expense is entailed. The interest of the owner is affected by the unforeseen delay, and there is the risk of a fall in prices during the long interval." When assessing compensation for a house gutted by fire, one would not be justified in informing the owner that the indemnity is to be lowered in view of the opportunity he now has of erecting a large five-storied residence yielding a heavy rental in place of his former small and low-rented cottage. The case of the burnt forest is not identical, but the analogy is sufficiently close to demonstrate the absurdity. A change in working of so important a nature cannot be imposed without the express consent of the owner.

To sum up, the proprietor has only his convenience to consider outside botanical and sylvicultural conditions; in any case he will realise exactly what the normal fellings would have brought in, that is to say, at the end of 40 years:—

Normal, if no fire had occurred.

First coupe of 400 francs at interest for (i) 20 years $= 400 \times 2{\cdot}094$ . .	$=837{\cdot}6$	1,237·60 francs.
Second coupe (ordinary) . . .	400	

Fire entailing premature felling at 15 years.

Compensation 173·34 francs at interest (i) for 40 years $= 173{\cdot}34 \times 3{\cdot}262$ . .	$=565{\cdot}4$	1,237·60 francs.
Felling at 15 years, 130 francs at (i) interest for 25 years $130 \times 2{\cdot}094$.	$=272{\cdot}2$	
Ordinary coupe	400	

Fire entailing felling at 40 years.

Compensation 85·1 francs at interest for (i) 40 years, $85{\cdot}1 \times 3{\cdot}262$ . . .	$=277{\cdot}6$	1,237·60 francs.
Coupe at 40 years	$=960$	

The reverse decision, both from the sylvicultural as well as the pecuniary point of view, would be arrived at if the coppice contained a marked proportion of beech, which loses its capacity for producing coppice at an early age, or of short-lived interior shrubs such as dogwood (Cornus); the

latter is in some demand for the manufacture of walking sticks and umbrella sticks, but its value, which is considerable for the marketable sizes, does not increase after about 20 years of age. In such case it would be advantageous in every direction to fell at 15 instead of 40 years.

According to such considerations will the adjudication vary. In any case, however, the organisation is disturbed, adversely affecting the exploitation, which has to be either advanced or retarded.

66. Legitimate method of estimation, with disorganisation of management.—A piece of simple-coppice is burnt at the age of 6; it forms part of a coupe that has to be felled at the period prescribed by the working plan—at 25 years; its value is then 400 francs.

The species composing the growing-stock preclude the exploitation from being deferred to 19+25=44 years; it must therefore take place at its 25—6=19th year, when it will yield:—

60 *Stères* of charcoal wood at 2 francs	.=120	180 francs.
1000 faggots at 6 francs per 100 . .	.= 60	

1. *Depreciation.*—The loss will be 400−180=220 francs in 19 years discounted to date at 3 per cent., the rate ascertained for this coppice in Section 43:—

(ii) 220 × 0·5703	=125·47 francs.
2. *Add* cost of cutting back: wages of woodcutter for 3 days at 3 francs . . .	= 9
Total loss .	=134·47 francs.
3. *Salvage.* Deduct sale amount of twigs cut, say	= 4
Indemnity .	=130·47 francs.

Verification.—The cost of cutting back must be deducted as it has to be disbursed by the proprietor, and the latter receives as net compensation 125·47 francs. Put out at compound interest for 19 years it becomes:—

(i) 125·47 × 1·7535	=220 francs.
In 19 years the re-growth will fetch . . .	=180
Total .	400 francs.

which is the sum normally expected from the area.

Empirical method.—This method is convenient but not very accurate and generally gives a higher figure than the more exact methods in the valuation of growing woods. It is applicable rather to amicable settlement out of court than to legal proceedings and arbitrament when large amounts are involved.

Initially, we must accept the theory that the values of a coppice at the ages m and n are proportionate to the square of their ages :—

$$\frac{X}{V}=\frac{M^2}{N^2}$$

The coppice burnt over at 6 years will be felled 19 years after, and will then yield $400 \times \frac{19^2}{25} = 231$ francs, as against 400 francs, the normal yield. The damages may therefore be assessed at the sum that at compound interest for 19 years will produce $400-231=169$ francs :—

This sum is $\frac{169}{1 \cdot 03^{19}} = 169 \times \overset{\text{(ii)}}{0 \cdot 57}$ . . . $=96 \cdot 33$ francs.

instead of 125·47 as found and verified above.

***Mixed method*—**

1. *Estimation of the growing stock* as in Section 64 . . . . . . = 70·95 francs.
2. *Depreciation.*—At the date prescribed in the working plan for the exploitation the burnt area, aged 19, will yield 180 francs, whereas normally at 25 years of age, it would equal the accumulation of a capital capable of producing 400 every 25 years :—

$400 \times \overset{\text{(iii)}}{0 \cdot 9143} \times \overset{\text{(i)}}{0 \cdot 7535}$ . . $=275 \cdot 57$ francs.

This loss of $275 \cdot 57 - 180 = 95 \cdot 57$ francs is sustained 19 years hence. Discounted to date it corresponds to a sum of $95 \cdot 57 \times \overset{\text{(ii)}}{0 \cdot 5703}$. = 54·52 francs.

Total	. 125·47 francs.
Add cost of cutting back (as before) . .	. 9
Loss	. 134·47 francs.
Salvage : deduct sale price of twigs cut back .	. 4
Net loss and compensation due	. 130·47 francs.

The result is identical with that obtained by the legitimate method above, but the process is more complicated, the

arguments more involved, the calculations longer and the risk of errors therefore greater.

Also it introduces a somewhat confusing combination of values of woods in growth and of depreciation, of ocular valuation of growing stock and assimilation of the same to a fictitious capital invested at compound interest. On the other hand, the legitimate methods detailed earlier are based, the one entirely on the principles of rent, and the other solely on actual sale prices. The position is clearly defined with or without disorganisation of management. In short, they are far simpler and clearer.

II.

Fire in Coppice-with-Standards.

Fire in a coppice-with-standards at the time of the exploitation.

Destruction of isolated standards.

67. Calculation for individual trees.—When standards have been so far injured by the fire as to necessitate their immediate felling, the consequent loss of revenue owing to their premature exploitation must be estimated. We will suppose that the fire took place at the time of felling in coppice-with-standards worked on a coppice rotation of 25 years. We need not consider the coppice as the felling will remove all traces of the fire.

A newly reserved standard, worth now 0·15 francs, would have reached the first class of commercial timber, *i.e.*, its greatest value, at between 100 and 125 years.

After full consideration of local economical conditions, markets, prices, etc., the exploitable age is fixed at 100 years as an average for the standards. At this age the tree under consideration would have been sold for 25 francs, which, discounted for 100—25=75 years at 4 per cent., becomes :—

(ii)
$$25 \times 0{\cdot}0528 = 1{\cdot}32 \text{ francs.}$$

The loss sustained is therefore 1·32—0·15=1·17 francs.

Similar calculations give the depreciation of a second rotation standard 50 years old, worth at the present date 2 francs :—

(ii)
$$25 \times 0{\cdot}141 - 2 = 1{\cdot}53 \text{ francs.}$$

and for a third rotation standard 75 years old, of present estimated value of 9 francs :—

(ii)

$$25 \times 0{\cdot}375 - 9 = 0{\cdot}38 \text{ francs.}$$

68. Tabular statement of standards destroyed.—The following table co-ordinates the operations and facilitates the general discounting :—

Standards.	Age at the time of the fire.	Average value at the time of the fire.	Depreciation.	
			Gross per tree, discounted to present date.	Net per tree, discounted to present date, *i.e.*, deducting present value.
	Years.	Francs.	Francs.	Francs.
New . . .	25	0·15	1·32	1·17
2nd rotation . .	50	2·0	3·53	1·53
3rd " . . .	75	9·0	9·38	0·38
4th " . .	100	25·0	...	...

This statement is somewhat too summary to reproduce with sufficient accuracy the true values. The demonstration of the method having been made, a few details will bring us nearer the reality.

69. Statement of correct values of standards destroyed.—When a large number of trees are in question, a mean value may be attributed to each class; but there is no reason why each tree should not be separately discounted and its individual valuation preserved. Moreover, in practice, while avoiding minutiæ, it is still necessary to maintain a distinction between the species.

It must also be noted that in most forests the standards do not pass from one class to the next with the absolute regularity ascribed to them in the subjoined table; a proportion remains in the same girth class for two rotations.

It is seldom that timber thus felled through necessity fetches its intrinsic value, timber merchants seek to profit by the forced sale and lower their offers in consequence.

The sums calculated above refer to depreciation owing to a compulsory premature felling. Certain circumstances add accessory costs: restocking, etc., these will be dealt with later, it is sufficient for the present to merely call attention to the possibility.

These observations now enable us to complete the last statement and to give more accurate figures of discount in the following one :—

Standards.	Age at the time of the fire.	Average normal value.		Sale price after the fire. (Salvage).		Depreciation; gross, discounted to present date.		Injury per tree.	
		Oak.	Beech, etc.	Oak.	Beech etc.	Oak.	Beech, etc.	Oak. Col. 7—Col. 5.	Beech etc. Col. 8—Col. 6.
1	2	3			6			9	10
	Years.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.
New	25	0·15	0·15	0·10	0·10	1·06	0·63	0·96	0·53
2nd-rotation, 0·5 to 0·89m .	50	1·50	1	1	0·70	2·82	1·70	1·82	1
2nd-rotation, 0·9 to 1·19m .	75	6·00	3			7·50	4·50	3·50	2·50
3rd rotation, 1·2 to 1·49m .	100	20	12						
3rd-rotation, 1·5 to 1·79m .	125	43	25						
4th-rotation	150								

70. Method of calculation for individual standards discussed.—The above simple calculation is applicable in the majority of cases: that is, when a few scattered standards are burnt.

Though it is not absolutely mathematically accurate, it is nevertheless very approximate and sufficiently correct to indicate the damage done, as will be seen in Section 77. When the premises are based on somewhat vague estimates admitting sensible divergences, absolute accuracy cannot be insisted on. Timber merchants, whatever the extent of their experience, differ in their estimates of the value of a standing crop and these discrepancies are exaggerated when the question is complicated by the necessity of allowing for damage, more or less extensive, due to fire.

It must be admitted too that all the standards will not be preserved till they reach the age of 100 years; but that is a mean age and some of them will remain ill they are 125

and even 150 years old in the case of oak, and up to 125 for certain other species, *e.g.*, maple.

There is nothing to prevent this question being given due weight. When the material justifies it the appraiser will take note of the consistence of the growing-stock, the distribution of the species, the promise of particular individual trees, etc. For instance, if the standards are too few, he can retain them all or allot but a fifth for felling at each of the rotations for the fixed period of 100 years. When the reserve of standards is normal and the relation between the increment and the rotation happens to be about double, good management will select about half for felling. These considerations will be further dealt with and in greater detail in Section 82.

Finally, it is equitable to place the owner in the least unfavourable situation and the onus of proof, in case of doubt, that trees affected were neither vigorous, well grown nor likely to attain a ripe old age, must rest with the party responsible for the fire.

Let us, however, concede the point that only half the standards will be retained for more than one or two rotations of the coppice; even then the results do not greatly diverge from the figures given in the table above. Indeed, at a rate of 4 per cent. the difference in money yield between two 1st-rotation standards of oak and beech felled at 100 and 75 years of age, taking due note of the woody growth that will replace the tree felled earlier than at 100 years, is only 0·20 francs.

Oak.

$$20 \times \overset{\text{(ii)}}{0{\cdot}0528} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad = 1{\cdot}056 \text{ francs.}$$

$$6 \times 0{\cdot}141 + 0{\cdot}15 \times \overset{\text{(ii)}}{0{\cdot}0528} \quad . \quad . \quad . \quad . \quad . \quad = 0{\cdot}854$$

Difference . 0·202 francs.

Beech.

$$12 \times \overset{\text{(ii)}}{0{\cdot}0528} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad = 0{\cdot}634 \text{ francs.}$$

$$3 \times 0{\cdot}141 + 0{\cdot}15 \times \overset{\text{(ii)}}{0{\cdot}0528} \quad . \quad . \quad . \quad . \quad . \quad = 0{\cdot}431$$

0·203 francs.

The difference remains at 0·20 between beech felled at 50 and 100 years, and the maximum is 0·55 for a tree of 50 years cut prematurely at 75 years. With a higher

exploitable age or a higher rate of interest, say, 5 per cent. (which also is more suitable for standards), the differences are much slighter and in some cases disappear.

If, nevertheless, these valuations are contested, another method, developed in Section 77, may be employed.

Destruction of a whole class of standards.

71. Working-plan prescriptions for marking standards.—The question of classifying the standards is simplified for the appraiser when the whole crop is destroyed so that all the standards have to be felled, for in that case definite directions replace all hypotheses. Such authority is found in the marking prescriptions of the working plan.

The prescriptions in the forest we will take as an example make the following recommendations:—Reservation per hectare to consist of 120 new, 60 2nd-rotation and 10 3rd-rotation standards, all material beyond this to be exploited. This amounts to removing as many of the older stems as there are new ones added, conforming to the following supplementary prescriptions: Oaks to be removed when they show signs of dying, are badly grown or too crowded: beech and miscellaneous to be cut out as soon as they reach the 3rd-rotation, with exceptions: the miscellaneous species to be limited to one-fifth of the total number of 2nd-rotation standards.

In practice, the marking prescriptions are intended rather for guidance than as strict rules. In the particular instance of a fire, however, the assessor of damages should treat them as imperative for they constitute his safeguard against objections.

72. Mechanism of standard marking in a forest where the standards are classed by age.—Passage of standards from one class to the next.—The classification of the standards of the upper story is rarely studied theoretically and it will be useful to demonstrate the passage from one class to another and the interdependence between the classes and the standards removed at successive fellings, by means of a tabular statement.

After each felling the normal stock of standards per hectare comprises 120 new standards (*baliveau*) from 0·20 to 0·55 m. in circumference; 60 2nd-rotation (*moderne*) from 0·60 to 1·15 m; and 10 3rd-rotation (*ancien*) of 1·20 metres and above.

Let us first consider a growing-stock of rapid growth, or forests where the standards are classified purely by age without reference to size. At the end of the rotation the 120 new standards pass into the 2nd class (2nd-rotation), the 60 2nd-rotation pass into the 3rd class, and the 10 3rd-rotation pass into the matured 4th class (*bis-ancien*).

To the reserve of standards are now added 120 new standards from among the poles grown up during the last rotation, and the same number of exploitable trees among the standards are removed. These are selected as follows: First the 10 standards of the 4th class, then 50 of the 3rd class, leaving 10 to reach the 4th class, and finally 60 of the 2nd class to complete the number.

The subjoined table sums up the operation :—

Normal coupe of one hectare at harvest.		Same coupe 25 years later.			Same coupe 50 years later.
		Before marking.	After marking.		
			Standards reserved.	Marked for felling.	
New standards .	120	?	120	...	
2nd-rotation . .	60	120	60	60	
3rd " . .	10	60	10	50	constitution identical.
4th " . .	0	10	0	10	
Total .	190	190	190	120	

73. Co-efficient of contingent loss.—Actually, through various accidental causes, there is a loss of about 20 per cent. of the new standards and 3 per cent. among the 2nd-rotation standards. In an authentic estimation it would be strictly correct to make allowance for this contingent loss, but here it merely introduces an element of confusion in a discussion already sufficiently difficult to follow. The arguments would be obscured without much gain if further complicated, since the point is a physiological one and our object is merely to demonstrate the methods of calculation. The reasoning will not lose its force since there is a way of taking these casualties into consideration without overburdening it.

The corrected table would be as follows :-

Normal coupe of one hectare at harvest.		Contingent loss.	Same coupe 25 years later.		
			Before marking.	After marking.	
				Standards reserved.	Marked for felling.
New selections .	120	20%=24	...	120	...
2nd-rotation . .	60	3%= 2	96	60	36
3rd „ . .	10	...	58	10	48
4th „ . .	0	...	10	...	10

The situation, however, is still not perfectly or completely represented in this manner, for the trees would not disappear without giving some return. It is better, for the sake of lucidity, not to reduce the number of standards but simply to lower their price.

A proportion of the casualties and decaying trees will be exploited at dates scattered throughout the rotation. Nevertheless, to allow for contingencies, we will give these trees the values they had at the beginning of the rotation and not the higher ones they would attain towards its end.

Owing to the loss of these trees, removed before maturity, the felling will yield :—

36 2nd-rotation standards and 24 casualties of the 1st rotation.
48 3rd- 2nd

The actual prices of 2nd and 3rd-rotation standards are 3·20 and 10·35 francs respectively against 2 and 10 quoted, so it is immaterial, from the financial point of view, whether we calculate with

36 2nd-rotation standards at 3·20 + 24 new standard windfalls at 0·15 = 118·80 francs.
48 3rd- do. at 10·35 + 2 2nd-rotation windfalls at 2 = 500·80 „

619·60

or (as in Section 44) :

60 2nd-rotation standards at 2 120 francs
50 3rd- „ „ at 10 500 „

620 francs.

This is the step actually taken in the analysis of the coppice-with-standard wood presented as example. These altered prices have the advantage of facilitating the calculations without in any way affecting the accuracy of the preceding tables. Consequently, no scruples need preclude their employment; they are correct from the money standpoint and clear as regards the distribution of the standards.

74. Destruction of new standards.—We will presume that a fire has killed both the coppice and the new standards just before the exploitation.

The coppice need not be considered as the damage is remedied by cutting back, the stools being re-invigorated to replace the crop with re-growth. Possibly, if the material has been injured the purchaser may claim damages from the author of the fire, but the owner is not directly affected.

The appended statement describes the gradations by which the overwood is restored, rotation by rotation; the deficit in each class of standards indicates the actual loss:—

Coupe at the time of the fire.		1st Rotation after the fire.			2nd Rotation after the fire.			3rd Rotation after the fire.		
		Before marking.	After marking.		Before marking.	After marking.		Before marking.	After marking.	
			Standards reserved.	Marked for felling.		Standards reserved.	Marked for felling.		Standards reserved.	Marked for felling.
New Standards burnt	120	...	120	...	...	120	...	...	120	...
1st-rotation .	60	...	...	loss 60	120	60	60	120	60	60
2nd „ .	10	60	10	50	...	...	loss 50	60	10	50
3rd „ .	0	10	...	10	10	...	10	...	...	loss 10

It is only in the 4th rotation, that is to say, after a lapse of 100 years, that the economical conditions that prevailed on the area prior to the mischief will be completely restored.

25 years after the fire the deficit will be of
60 2nd-rotation standards at 2 = 120 francs.

50 years after the fire the deficit will be of
50 3rd-rotation standards at 10 = 500 „

75 years after the fire the deficit will be of
10 4th-rotation standards at 25 = 250 „

These sums discounted for 25, 50 and 75 years respectively, at the rate for coppice-with-standards, say, 4 per cent., give the actual money loss :—

$$\left.\begin{array}{l}120 \times 0{\cdot}375 = 45 \\ 500 \times 0{\cdot}141 = 70{\cdot}5 \\ 250 \times 0{\cdot}0528 = 13{\cdot}2\end{array}\right\} \quad 128{\cdot}7$$

(ii)

Deduct salvage, say	10
Damage	118·7 francs.

A rate of 4 per cent. is employed here and will be adhered to in the next six sections, but it must not be taken to mean that this is the correct rate for this type of forest, it is adopted for the sake of simplicity.

In Section 50 we have already seen a refutation of the objection that prices cannot be guaranteed so long in advance. Here again, we will see that a fall in prices produces but the slightest alteration in the indemnity.

Supposing that the anticipated prices are realised for the first two rotations but that there is a fall of $\frac{1}{3}$ at the end of the third.

There will be a correlated fall in the rate of 0·5 per cent. The value of the standards in deficit will then be 167 instead of 250, and this discounted will be 167 × 0·0758 (ii) = 12·70 as against 13·20 francs; the difference of 0·5 francs is insignificant.

75. Destruction of the standards of the 2nd-rotation.—A table analogous to the last represents the loss when the whole of the 2nd-rotation standards are destroyed.

Coupe at the time of the fire.		1st ROTATION AFTER THE FIRE. Before marking.	1st ROTATION AFTER THE FIRE. After marking. Standards reserved.	1st ROTATION AFTER THE FIRE. After marking. Marked for felling.	2nd ROTATION AFTER THE FIRE. Before marking.	2nd ROTATION AFTER THE FIRE. After marking. Standards reserved.	2nd ROTATION AFTER THE FIRE. After marking. Marked for felling.
New standards	120	...	120	...	...	120	...
2nd-rotation burnt	60	120	60	60	120	60	60
3rd „	10	...	...	loss 50	60	10	50
4th „	...	10	...	10	...	...	loss 10

The overwood is restored at the 3rd-rotation :—

25 years after the fire the loss will be of
50 3rd-rotation standards at 10 francs or 500 francs.
50 years after the fire the loss will be of
10 4th-rotation standards at 25 francs or 250 francs.

These amounts discounted respectively for 25 and 50 years represent the damages :—

(ii)

$$\left.\begin{array}{r}500 \times 0{\cdot}375 = 187{\cdot}50 \\ 250 \times 0{\cdot}141 = 35{\cdot}25\end{array}\right\} 222{\cdot}75 \text{ francs.}$$

Deduct salvage . 84

Net amount of damage . 138·75 francs.

76. Destruction of 3rd-rotation standards.—The same process shows the overwood restored at the end of two rotations, with a loss of 10 4th-rotation standards (*vielles écorces*) 25 years after the occurrence of the fire; these are worth 250 francs, which sum discounted for 25 years, becomes :—

(ii)

$250 \times 0{\cdot}375 = 93{\cdot}75$ francs.

Deduct salvage . 70 „

Net indemnity . 23·75 francs.

77. Comparison between these methods and that of Section 67.—A new method of estimating the injury is suggested by this general study of all cases likely to occur when a few standards have been destroyed. It does not materially alter the results of direct estimation which appear at the beginning of the chapter on coppice-with-standards, but based as it is on the bulk of the class to which the trees burnt belong and derived from the working plan, it removes all ground for objection. The previous calculations arrived at the following amounts :—

	New standards.	2nd rotation	3rd rotation
Gross indemnity	$\frac{128{\cdot}7}{120} = 1{\cdot}07$	$\frac{222{\cdot}75}{60} = 3{\cdot}71$	$\frac{93{\cdot}75}{10} = 9{\cdot}38$
Salvage to be deducted	$\frac{10}{120} = 0{\cdot}08$	$\frac{84}{60} = 1{\cdot}40$	$\frac{70}{10} = 7$
Net indemnity per tree	0·99 francs.	2·31 francs.	2·38 francs.

The working out of the process of Section 67 leads to results but slightly different.

Let us now introduce as basis the same units :—the new standard would in 100 years have reached the 3rd class and a value of 25 francs ; in 125 years it would have been valued at 43 francs. Now discount for 75 years gives a value of 1·24 francs and for 100 years of 0·77 francs. The mean of these two values is almost exactly the sum 0·99 francs arrived at above.

In doubling its age the 50-year-old standard enters into the 3rd class ; 25 francs discounted for that period, after deducting the salvage, becomes 2·20 francs, which approaches the figure 2·31 found above.

Finally, in the case of the 3rd class standard which enters the 4th class in 25 years, discount reduces its value exactly to 2·38 francs as above.

It follows that ordinarily we can dispense with the lengthy process of detailed analysis of the several classes of standards to which the trees burnt belong. The first method is much simpler.

78. Selection of standards in a stored coppice where the standards are classed by size.—The classifications of standards considered hitherto are purely theoretical; they are skeleton schemes employed in order to simplify the argument. In nature vegetation is not so regular. The following example will present one of the usual variations ; any others that may occur can be readily reduced to figures by analogous reasoning.

Almost all soils vary in fertility to so great an extent that in adjoining coupes, and even in different parts of the same coupe, the several ages cannot be readily distinguished. To avoid confusion when marking and felling, one is compelled to *classify the standards* entirely *by size*. This is certainly the most practicable system. In all detailed studies of coppice-with-standards the arguments have been based on a classification by diameter, the ages being referred to merely to keep in touch with the rate of interest.

Practically throughout France three girth sub-classes for 2nd class standards (*modernes*) are recognised, *viz.* :—either 0·6, 0·8 and 1 metre or 0·5, 0·75 and 1 metre ; and those above 1·20 or 1·25 are considered to be of the 3rd class (*anciens*). Let us conform to this observance.

Ring-counting on trees felled in the district under consideration and an examination of the marking-register reveal that the standards pass through one girth class (0·2 metre) in 12 or 13 years, or through two classes in the rotation of

25 years. Actually, such regularity of growth for all species, at all ages, is not met with in nature; the increment measured along the radius gradually decreases. Strictly speaking, the rate of progression should be diminished in the following tables, of which too the number should be increased to allow for biological variations. No new difficulty, however, is presented thereby, and it is better to simplify the explanation as far as possible seeing that no fresh principle is involved.

Let us follow the career of the standards left in the growing-stock immediately after the felling. The 2nd class standards are divided into three sub-classes; one-third of them (20) will be twice marked in the 2nd class and the remainder (40) will pass into the 3rd class in a single rotation. The details are as follows:—At the time of felling a normal coupe of one hectare contains:—

120 1st-class new standards of 0·20 to 0·40 m.
60 2nd-class standards $\begin{cases} \text{20 of 0·60 m.} \\ \text{20 of 0·80 m.} \\ \text{20 of 1} \end{cases}$
10 3rd-class standards of 1·20 m. and above.

Twenty-five years later the 120 first-class standards will have passed into the 2nd class; the 20 2nd-class of 0·6 will have attained 1 m without leaving their class, so that there will now be 120+20 2nd-class standards; the remaining 40 of 0·8 and 1 m will have become 3rd class. The 10 3rd-class trees will now be placed in the 4th class (*bis-anciens* or *vielles écorces*). Consequently, the normal marking will provide for felling 60+20 2nd-class and 40 3rd or 4th-class (60 −20) and not 60, (50 + 10) the total number of 2nd class as is usually stated by an exaggerated simplification. The table will now be:—

Normal coupe of one hectare before marking.		Same coupe 25 years later. Standards reserved.	Same coupe 25 years later. Marked for felling.	Same coupe 50 years later.
New (1st-class) standards	...	120	...	
2nd-class standards {120, 20}	140	60	80	Constitution identical.
3rd-class ,,	40	10	30	
4th-class ,,	10	...	10	
	190	190	120	

79. Destruction of all the standards in the same stored coppice.—The following statement tabulates the girths and average values of the standards burnt :—

Girths at Height of 1·30 m.	1st-class standards.			2nd-class standards.			3rd-class standards.			Value.		
										Per tree.		
	Oak.	Beech.	Miscellaneous.	Oak.	Beech.	Miscellaneous.	Oak.	Beech.	Miscellaneous.	Oak. francs.	Beech, etc. francs.	Total francs.
20	5	15	20	...	...	...	...	...	...	0·10	0·10	6
40	25	15	20	...	...	...	...	...	...	0·20	0·20	12
60	...	...	...	10	5	5	...	..	...	0·80	0·70	15
80	...	...	...	12	4	4	...	...	...	2	1·40	35·2
100	...	...	...	12	6	2	...	...	...	4	2	64
120	...	...	...	...	...	...	3	...	...	8	3·50	24
140	...	...	...	...	...	...	2	1	1	16	9·50	51
160	...	...	...	...	...	...	1	...	...	25	14	25
180	...	...	...	...	...	...	1	...	...	35	20	35
200	...	...	...	...	...	...	1	...	...	50	30	50
220	...	...	...	...	...	...	...	...	...	70	40	
240	...	...	...	...	...	...	...	...	...	90	...	317·2

Had these standards not disappeared prematurely they would have been exploited in the following rotations :—

(See table on page 134.)

Girths at Height of 1·30 Metres.	1st Rotation after the Fire.									2nd Rotation after the Fire.									3rd Rotation after the Fire.						4th Rotation.					5th Rotation.		
	2nd Class.			3rd Class.			Trees Exploited.			2nd Class.			3rd Class.			Trees Exploited.			3rd Class.			Trees Exploited.			3rd Class.		Trees Exploited.			Trees Exploited.		
							Number.									Number.						Number.					Number.			Number.		
	Oak.	Beech.	Miscellaneous.	Oak.	Beech.	Miscellaneous.	Oak.	Beech, etc.	Value.	Oak.	Beech.	Miscellaneous.	Oak.	Beech.	Miscellaneous.	Oak.	Beech, etc.	Value.	Oak.	Beech.	Miscellaneous.	Oak.	Beech, etc.	Value.	Oak.	Miscellaneous.	Oak.	Beech, etc.	Value.	Oak.	Beech, etc.	Value.
									Fr.									Fr.						Fr.					Fr.			Fr.
60	9	7	4	...	...	...	16	24	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
80	13	3	4	...	...	...	12	28	63	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
100	10	5	5	...	...	...	...	...	...	9	7	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
120	...	...	...	3	1	1	9	6	93	...	...	...	5	...	1	8	6	85	...	...	...	...	...	...	...	...	...	...	...	...	...	...
140	...	...	...	2	...	...	10	8	236	...	...	...	2	...	...	8	10	223	2	1	1	7	9	197	...	...	..	...	...	...	...	...
160	...	...	...	1	...	..	2	...	50	...	...	...	1	...	...	2	2	78	1	...	...	4	1	114	...	...	...	...	...	...	...	...
180	...	...	...	1	...	...	1	2	75	..	...	...	...	...	...	2	...	70	1	...	...	1	...	35	1	1	1	1	55	...	...	...
200	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1	...	50	1	...	...	...	...	...	...	...
220	...	...	...	...	...	...	1	...	70	...	...	...	...	...	...	1	...	70	...	...	...	...	...	...	...	...	1	...	70	1	...	110
240	.	...	...		...	...	1	...	90	..	...	...	...	...	...	1	...	90	...	...	...	1	...	90	...	...	...	...	...	1	1	90
									707									616						486					125			200

We will presume that the timber merchants did not take advantage of the owner's plight to reduce their rates, and that the timber realised the full value : 317·20 francs. But for the fire, the owner would have realised 707, 616, 486, 125 and 200 francs at the end of 25, 50, 75, 100 and 125 years respectively. These sums discounted to date at 4 per cent. become :—

(ii)

707	× 0·375	=	265·13	francs.
616	× 0·141	=	86·86	„
486	× 0·0528	=	25·66	„
125	× 0·0198	=	2·47	„
200	× 0·0074	=	1·48	„
			381·60	francs.

The loss on account of these standards is therefore 381·6—317·20= 64·40 francs.

This subject has already been touched upon in a journal, but the values of the trees were calculated as if they were all to be realised at the term of the first rotation succeeding the fire. This period is too short for most of them, especially the oaks, which would not by then have attained their greatest mean increment, nor their maximum value.

Fire in coppice-with-standards during the course of the rotation.

80. Restoration of the overwood.—Should the fire occur 10 years after the felling, for instance, the restoration of the upper story will necessitate a longer delay, for at the end of the curtailed rotation succeeding the fire the 15 years old coppice will not be sufficiently advanced to provide satisfactory standards.

Two alternatives will present themselves : either to cut back the whole coppice or to leave it to grow for another rotation ; the decision will depend upon the species as well as local market rates.

The extent of the damage will be calculated as laid down in Section 64 or Section 66. This has been discussed in Section 65.

A new subject for consideration arises here : the standards selected from the 40 years old coppice will be far superior to those from 25 years old shoots. The appraisers will have to decide after a careful comparison of the results of the diverse combinations.

As regards the standards, the subjoined table shows the successive losses undergone and the steps necessary for reconstruction—

Composition of the growing-stock at 10 years, at the time of the fire.	1st Rotation (curtailed), 15 years after the fire.			2nd Rotation, 40 years after the fire.			3rd Rotation, 65 years after the fire.			4th Rotation, 90 years after the fire.		
	Before marking.	After marking. Standards.	After marking. Marked for felling.	Before marking.	After marking. Standards.	After marking. Marked for felling.	Before marking.	After marking. Standards.	After marking. Marked for felling.	Before marking.	After marking. Standards.	After marking. Marked for felling.
New standards 120 burnt.	...	...	...	...	120	...	...	120	...	...	120	...
2nd-class standards 60 burnt.	...	...	deficit 60	...	...	deficit 60	120	60	60	120	60	60
3rd-class standards 10 burnt.	60	10	50	...	...	deficit 50	...	...	deficit 50	60	10	50
4th-class standards.	10	...	10	10	...	10	...	...	deficit 10	...	...	deficit 10

At the fifth rotation, or 115 years after the conflagration, the coupe will be restored to its original condition—

15 years after the fire, *i.e.*, at the end of the 1st rotation (curtailed) the deficit will be of .	60 2nd-class standards	@ 2	= 120 fr.
15 + 25 years after the fire, *i.e.*, at the end of the 2nd rotation (curtailed) the deficit will be of	60 " 50 3rd-class	@ 2 @ 10	620 fr.
15 + 2 × 25 years after the fire, *i.e.*, at the end of the 3rd rotation (curtailed) the deficit will be of	50 " 10 4th class	@ 10 @ 25	750 fr.
15 + 3 × 25 years after the fire, *i.e.*, at the end of the 4th rotation (curtailed) the deficit will be of	10	@ 25	= 250 fr.

These amounts must be discounted for 15, 40, 65 and 90 years, respectively.

(ii)

$$\left.\begin{aligned} 120 \times 0{\cdot}555 &= 66{\cdot}6 \\ 620 \times 0{\cdot}208 &= 129 \\ 750 \times 0{\cdot}0781 &= 58{\cdot}6 \\ 250 \times 0{\cdot}0293 &= 7{\cdot}3 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad 261{\cdot}5$$

Deduct salvage, say 17

244·5 francs.

Where the standards are classified by girth instead of by age, the matter becomes more complicated, but the principle and method remain unchanged. It must be admitted that the new standards burnt are cut back and produce coppice, but their productiveness, weakened by the fire, is not likely to be important during the next 15 years.

81. Weakness of new standards.—Reduced height-growth of standards.—Presuming the fire to have occurred at the fifth year of the rotation, and to have killed the coppice without affecting the over-wood: (1) In 20 years, at the normal term of the rotation, the poles may be considered, taken one with the other, sufficiently advanced for new standards to be selected from among them. Subsequently, however, isolation will result in some being broken and others bent, let us say $\frac{1}{3}$. The customary proportion of losses in the forest in question is $\frac{1}{5}$; therefore actual depreciation owing to the immaturity of the new standards works out to $(\frac{1}{3}-\frac{1}{5})120=16$. The indemnity on the 16 new standards is calculated as in Section 79.

If, however, the coppice cannot supply suitable poles for selection as standards, it will be clean felled, or, better still, left over for another rotation, when the indemnity on this account is calculated as in the last section.

(2) The value of the standards depends upon their height and the full height cannot be attained unblemished without the influence of the coppice. The experimental loppings recommended by some sylviculturists have ended in disappointment. It is on this score that long rotations are recommended: "When isolated the height increment of a tree stagnates, consequently, it is desirable that it should have approached its maximum at the time the coppice is felled, hence the advisability of a lengthened rotation."

"Another advantage is found in high boles: the further removed the crowns are above the soil the less injurious is the shade of the standards." This latter remark refers to the indirect action of the coppice on itself. Two other causes of lengthened boles subsist: the pressure of the lower story under the standards, and the canopy of the standards themselves, which cause the death of their own lower branches. We need not consider the latter case since it is independent of fires, but these exert a distinct effect on the other influences.

Cut over before its normal exploitable age (20 instead of 25 years), the coppice will not have reached its normal height-growth and will not therefore exercise its full influence in effecting the natural pruning of the boles of the future standards. The lower branches, which will not have disappeared as they should, will continue to grow, precluding the utilisation as timber of that portion of the trunk from which they issue. Should they subsequently die and dry on those individuals which are retained for a third or fourth rotation, it will be but to leave large holes or defects. Either way, by their presence or through the decay of their stubs, the upper portion of the trunk will be depreciated in value and fit only for fuel. The indemnity for this loss is fixed at the difference between the value of timber and that of fuel.

It is the age of the re-growth at the date of felling fixed by the working plan that is the determining factor in the amount of the indemnity. The height of the coppice at its customary age of felling is 8 metres; at 20 years it is only $6\frac{1}{2}$ metres. For at least $\frac{2}{3}$ of this difference or 1 metre natural pruning will not come into play.

This is confirmed by an inspection of neighbouring woods of identical aspect, altitude, soil, density and composition. In those felled-over at 20 years, the overwood shows average clean boles of 5 to 6 metres instead of 6 to 7, as in the forest under consideration.

During the rotation of 25 years the girth increment is about 40 c.m. Actually, it is true that absolute regularity does not occur, and two or three tables analogous to those given below should be drawn up; for the sake of simplicity, however, a single one is given and the principle is not affected.

Oaks of over 60 years and beech, etc., over 50 years, *i.e.*, those trees over 0·9 m. and 0·8 m. respectively, will be omitted.

In trees above these girths the branches are too well developed to be eradicated by the influence of the coppice, and even were they to disappear it would be but to leave wounds not easily healed and resulting in even greater blemishes.

The following tabular statement is derived from an enumeration and valuation of the standards on foot.

Consistence of the upper story at the time of the fire—Average price per cubic metre—Loss per tree.

Girth at 1·30 metres.	Height of trunk over 25-year old coppice.	Number of Standards.		Volume standing over coppice of		Loss of timber per tree.	Price per cubic metre; timber.		Price per cubic metre; fuel.		Deficit per cubic metre.		Deficit per tree.	
		Oak.	Beech, miscellaneous.	25 years.	20 years.		Oak.	Beech, miscellaneous.	Oak.	Beech, miscellaneous.	Col. 8—Col. 10, Oak	Col. 9—Col 11. Beech, etc.	Col. 7 × Col. 12, Oak.	Col. 7 × Col. 13, Beech, etc.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				c. m.	c. m.	c. m.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.
0·20	4	25	35	...	...	...	...	...	...	...	...	...	...	...
0·40	4	25	35	...	...	...	...	...	...	...	...	...	...	...
0·60	5	10	10	0·090	0·070	0·02	9	10	6	10	3	...	0·06	...
0·80	5	12	4	0·160	0·130	0·03	12	10	6	10	6	...	0·18	...
1	6	...	...	0·300	0 250	0·05	15	12	7	12	8	...	0·4	...
1·20	6	...	...	0·440	0·370	0·07	20	12	7	12	13	...	0·91	...
1·40	6	...	...	0·600	0·500	0·1	25	15	7	12	18	3	1·8	0·3
1·60	7	...	...	0·910	0·790	0·12	30	17	7	12	23	5	2·76	0·6
1·80	7	...	...	1·160	0·990	0·17	33	18	7	12	26	6	4·42	1·02
2	7	...	...	1·430	1·220	0·21	36	19	7	12	29	7	6·09	1·47
2·20	8	...	...	1·970	1·730	0·24	40	20	7	12	33	8	7·92	1·92
2·40	8	...	...	2·350	2·060	0·29	50	...	7	12	43	...	12·47	...

According to the marking prescriptions these trees would have been felled on the following dates:—

Girth at 1·30 metre.	1st Rotation after the fire.					2nd Rotation after the fire.					3rd Rotation after the fire.					4th Rotation after the fire.					5th Rotation after the fire.				
	Oak.	Beech and miscellaneous.	Loss for each species priced as in last table. Oak.	Loss for each species priced as in last table. Beech and miscellaneous.	Total loss.	Oak.	Beech and miscellaneous.	Loss for each species priced as in last table. Oak.	Loss for each species priced as in last table. Beech and miscellaneous.	Total loss.	Oak.	Beech and miscellaneous.	Loss for each species priced as in last table. Oak.	Loss for each species priced as in last table. Beech and miscellaneous.	Total loss.	Oak.	Beech and miscellaneous.	Loss for each species priced as in last table. Oak.	Loss for each species priced as in last table. Beech and miscellaneous.	Total loss.	Oak.	Beech and miscellaneous.	Loss for each species priced as in last table. Oak.	Loss for each species priced as in last table. Beech and miscellaneous.	Total loss.
			Fr.		Fr.			Fr.	Fr.	Fr.			Fr.	Fr.	Fr.			Fr.	Fr.	Fr.			Fr.	Fr.	
0·6	16	24	0·96	...	0·96	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0·8	12	28	2·16	...	2·16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1·20	9	2	8·19	...	8·19	8	6	7·28	...	7·28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1·40	...	...	...	...	...	8	10	·4	3	17·14	7	9	12·6	2·7	15·3	...	...	...	...	...	...	...	...	...	...
1·60	...	...	...	...	...	2	2	5·52	1·2	6·72	4	1	11·04	0·6	11·64	...	...	...	...	...	...	...	...	...	...
1·80	...	...	...	...	...	...	...	...	...	...	1	...	4·42	...	4·42	1	1	4·42	1·02	5·44	...	...	...	...	...
2	...	...	...	...	...	...	...	...	...	...	1	...	6·09	...	6·09	...	...	...	...	...	...	...	...	...	...
2·20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	7·92	...	7·92	1	1	7·92	1·92	9·84
2·40	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	12·47	...	12·47
					11·31					31·4					37·45					13·36					22·31

These losses, however, will date only from 20, 45, 70, 95 and 120 years hence; discounted to date at 5·25 per cent. they become:—

(ii)

$$
\begin{aligned}
11{\cdot}31 \times 0{\cdot}359 &= 4{\cdot}06 \\
31{\cdot}40 \times 0{\cdot}0994 &= 3{\cdot}12 \\
37{\cdot}45 \times 0{\cdot}0275 &= 1{\cdot}03 \\
13{\cdot}36 \times 0{\cdot}0075 &= 0{\cdot}10 \\
22{\cdot}31 \times 0{\cdot}00207 &= 0{\cdot}05 \\
\hline
&\ 8{\cdot}36
\end{aligned}
$$

This sum of 8·36 francs represents the loss caused to the existing standards owing to decreased height-growth resulting from the premature felling of the coppice.

At the next rotation the standards selected from the re-growth will be only 20 years old, and will have shorter boles than those of normal years. Moreover, the natural pruning due to the influence of the coppice will not be exercised to the extent the extra five years of growth would allow of, and when it eventually takes effect in the second rotation, it will be applied to larger and less responsive branches.

The following table shows the result on all the standards of the future.

Exploitation of the new standards to be selected from the coppice shoots at the next rotation (20 years from date of the fire.)

Girth at 1·30 metres.	New Standards selected 20 years after the fire.		2nd Rotation 45 years after the fire.			3rd Rotation 70 years after the fire.			4th Rotation 95 years after the fire.			5th Rotation 120 years after the fire.			6th Rotation 145 years after the fire.		
	Oak.	Beech and miscellaneous.	Oak exploited.	Beech, etc., exploited.	Total loss.	Oak exploited.	Beech, etc., exploited.	Total loss.	Oak exploited.	Beech, etc., exploited.	Total loss.	Oak exploited.	Beech, etc., exploited.	Total loss.	Oak exploited.	Beech, etc. exploited.	Total loss.
					Fr.			Fr.			Fr.			Fr.			Fr.
0·20	25	35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0·40	25	35	...	...	...	...	..	...	...	...	...	...	...	...	.	...	...
0·60	...	...	9	13	0·54	...	...	...	...	...	...	...	...	...	...	...	...
0·80	...	...	9	13	1·62	...	...	...	...	...	...	...	...	...	...	...	...
1·	...	...	...	...	..	4	13	1·60	...	...	...	...	...	...	...	...	...
1·20	...	...	...	...	...	4	13	3·64	...	...	...	...	...	...	...	...	...
1·40	...	...	...	...	...	...	...	...	7	6	14·4	...	...	...	...	...	...
1·60	...	...	...	...	...	...	...	...	5	6	17·4	...	...	...	...	...	...
1·80	...	...	...	...	...	...	...	...	...	...	...	5	3	25·16	...	...	...
2·	...	...	...	...	...	...	...	...	...	...	...	5	2	33·39	...	...	...
2·20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	9·84
2·40	...	...	...	...	...	...	...	..	...	...	...	...	...	...	1	...	12·47
					2·16			5·24			31·8			58·55			22·31

These losses of 2·16 francs, 5·24 francs, 31·8 francs, 58·55 francs, and 22·31 francs occur in 45, 70, 95, 120 and 145 years. They must therefore be discounted to date at $5\frac{1}{4}$ per cent. as follows :—

(ii)

$$
\begin{aligned}
2{\cdot}16 \times 0{\cdot}0994 &= 0{\cdot}21 \text{ francs.} \\
5{\cdot}24 \times 0{\cdot}0275 &= 0{\cdot}14 \\
31{\cdot}80 \times 0{\cdot}0075 &= 0{\cdot}24 \\
58{\cdot}55 \times 0{\cdot}00207 &= 0{\cdot}12 \\
22{\cdot}31 \times 0{\cdot}000566 &= 0{\cdot}01 \\
\hline
& 0{\cdot}72 \text{ francs.}
\end{aligned}
$$

This sum 0·72 francs added to that of 8·36 francs calculated above, gives the cumulative depreciation owing to loss of height-growth.

The above example has been given at length as a demonstration, in practice it would be permissible to neglect such unimportant values, or else the damage would be estimated in a less intricate though less accurate manner. However, with a shorter term of discount or at a smaller rate of interest, the loss might become more noteworthy. Thus at a rate of 3 per cent. the last figure 0·72 francs would become 5·14 francs or a loss seven times heavier.

82. Normal reserve of standards. Co-efficient of increment.—These arguments presume a normal stock of standards. Wherever it diverged from the marking prescriptions the management proposed to bring it back to the normal at the time the fire supervened and interrupted the reconstitution. The projects of the owner are compulsory, and the appraisers are bound to adopt them.

When a few standards only are burnt one need hardly give this matter a thought; but when the fire has been serious, involving the major portion of the overwood, the reconstitution of the crop in accordance with the terms of the working plan must be proceeded with.

The standards must therefore be increased or decreased in number so as to restore the equilibrium in one or two fellings. This will depend upon the rapidity and quality of growth in the area and must maintain rational proportions between the standards and the coppice suitable to the conditions of the locality and to the species.

M. Watier has drawn up a model prescription which calls for due recognition: "Coppice must be given sufficient room if it is desired to perpetuate the system. There is a

limit to the volume of the standards that a stored-coppice can contain on the eve of the felling. It is this maximum that the management should endeavour to obtain ; it is determined by sample plots carefully selected in the forest itself or in adjacent similar areas."

As pointed out by M. Boppe, it sometimes happens that owing to the length of the rotation the standards, though originally normal for the type selected, double their volume. In such cases, as in our examples, the volume reserved is equivalent to the volume removed.

This equilibrium between the standards and the coppice, always desirable, is sometimes imperative, as, for instance, when the forest is subject to rights, since it must then be made to yield constantly products of the same value.

It has been said that the overwood so managed yields a rate of $3\frac{1}{2}$ per cent. with a rotation of 20 years, $2\frac{3}{4}$ per cent. if of 25 years, and $2\frac{1}{4}$ per cent. for one of 30 years, since capital at $3\frac{1}{2}$, $2\frac{3}{4}$, and $2\frac{1}{4}$ per cent. doubles itself in 20, 25 and 30 years respectively. This observation is open to misconstruction for it should apply to the *timber-capital* and not to the *money-capital*. The latter, it must be remembered, embraces, besides the growing stock, the soil and the *ensouchement*.

Control books are as essential for coppice-with-standards as for high forest if one is not to work in the dark.

Specimens of control books, entailing but little work in posting, are given below. The appraiser will be glad of their assistance.

For small-sized coupes the sizes of the standards are entered in the marking registers as follows:—

Marking register.

* * * * * * * * * * *

1st-class (new) standards { Oak. Beech. Miscellaneous

60	80	100

2nd ,, ,, { Oak. Beech. Miscellaneous

120	140	160	180	2

3rd ,, ,, { Oak. Beech.

The heights are quoted as well as for the trees to be removed. The volume of the new standards is calculated

as a whole. As recommended by M. Watier, it is desirable to indicate the sizes up to which the trees remain sound. Unobjectionable as this arrangement is in theory, it is not very practical where extensive coupes have to be dealt with; it is too prolix, and delays and complicates the recording. If we agree to neglect the increment of the growing-stock from the time of the marking of the standards to the final felling, it will be more convenient, at the time of the latter operation, to maintain the register as follows. This amendment enables us to give to the record of the yield a more intelligent form which, at the same time, will be of greater assistance to the administration. For managers, with some exceptions, have rarely even an approximate knowledge of the contents of their forests.

Register of yield.—Left hand page.

* * * * * * * * * * *

Enumeration of standards.

		Oak.	Numbers.	Beech.	Numbers.	Miscellaneous.	Numbers.
Standards.	2nd class.	60 . .					
		80 . .					
		100 . .					
		Accidental falls					
		Totals . .					
		Unmarked .					
	3rd class.	120 . .					
		140 . .					
		160 . .					
		180 . .					
		Accidental falls					
		Totals . .					

New standards.	Casualties.	Total.	Unmarked.
Oak. Beech. Miscellaneous.		1,700	

Register of yield.—Right hand page.

* * * * * * * * * * *

Value measured in 1902.

		Oak.			Beech.			Miscellaneous.		
	60									
	80									
	100									
	120									
	140									
	...									
Losses										

	c. m.
Total of boles of standards . . .	60
Tops: 2/3 . .	40
New standards: 1,700 × 0·02 . . .	34
Total volume .	134

Of course the 'unmarked' are added to the enumeration, but not the casualties.

M. Watier extols this system of control in the following words: "From the marking register and the register of yield a complete and detailed inventory of the material in existence at each exploitation is obtainable, and the balance sheet of the forest can be drawn out at any time. Since they furnish the composition and volume of the stock of standards at the last felling, by measuring the trees just before the next exploitation we can ascertain the increment during the rotation.

We shall find, for example, that the volume of 50 cubic metres has increased to 125 c.m., *i.e.*, $50 \times 2{\cdot}5$. Consequently, the reserve of standards should be $\frac{V}{2{\cdot}5}$, the large, medium and small trees being in suitable proportions. This factor 2·5 may be termed the *co-efficient of increment* for the standards. Its development entails a supplementary operation—the enumeration of standing saleable produce; but

this operation need only be carried out once. Pending its revision the co-efficient can be employed, and its verification will be effected later and without extra work by a mere comparison of the volumes at the beginning and at the end of the rotation.

The precise and conscientious experiments of M. Watier have shown that this co-efficient is almost constant and only varies from 2·4 to 2·9 for a rotation of 30 years.

Observations on different soils by age classes have proved that it remains within two to three, whatever the quality of the locality, being generally approximately 2·5 for a 30 years' rotation; a little less for 25 years, and a little more at 35 years. Should the data available not permit of the exact factor being calculated, an arbitrary figure can be temporarily fixed according to the notes above.

The distribution of the three classes: small, medium and large timber, is established in accordance with actual statistics and a study of the forest itself.

Correlation of the exploitations of the two storeys: standards and coppice.

83. Fluctuations in the yield of the coppice resulting on the removal and restoration of the overwood.—M. Puton is of opinion that the value of each coppice cutting must be enhanced in proportion with the increased air and light which reach the re-growth when freed of the overwood. Thus, in the example in Section 44 where the whole crop was destroyed, at the next felling after the fire the coppice, denser and better grown, will realise 400 instead of 250 francs. At the 2nd and 3rd harvests the revenue would be 360 francs and 310 francs, respectively, falling back to 250 francs at the 4th, under the influence of the gradually restored overwood. Discounted for 25, 50 and 75 years these inflated revenues should go to diminish the amount of indemnity payable. The whole process is interesting and is therefore given in detail as follows:—

According to the marking prescriptions we have:—

2nd-rotation standards:	120—60 =	60 at 2 francs =	120 francs.
3rd " " :	60—10 =	50 at 10 francs =	500
4th " " :		10 at 25 francs =	250
		Trees	. 870 } 1,120 francs
Coppice less the new standards selected for reservation			250 }

Supposing the whole coupe to have been destroyed at 10 years of age, the material was then worth :—

120 new standards of 35 years of age at 0·20 francs	=	24 francs.
60 2nd-rotation standards of 60 years of age at 4 francs	=	240
10 3rd-rotation standards of 85 to 100 years of age at 13 francs	=	130
Trees	.	394
Coppice : 400 faggots at 5 francs per 100	.	20
		414

The indemnity for actual damage to material is therefore 414 francs.

Let us now trace out the injury done to the growing-stock, following the different phases of reconstitution :—

1. Take the situation at 15 years, *i.e.*, at the date when under normal conditions the coupe of 25 years would have been exploited ; it would then have been worth : 1,120 francs.

In its place we have only a simple coppice of 15 years, in which no stems fit for selection as standards are to be found. Its value is estimated at 1,500 faggots at 5 per 100 . . . . . . = 75

Loss . 1,045

Discounted for 15 years at 4 per cent. $1{,}045 \dfrac{1}{1{\cdot}03^{15}}$
(ii)
$= 1{,}045 \times 0{\cdot}5553 \qquad = 580{\cdot}3$

2. In 15 + 25 = 40 years we should have had another coupe worth 1,120

In its place we shall have a simple coppice of 25 years, in which 120 new standards will be reserved ; it is worth . . 400

Loss . 720

Discounted for 40 years at 4 per cent.:
(ii)
780 × 0·2083 . . . . = 150

3. In 40 + 25 = 65 years, there would have been a coupe worth 1,120

Carried over 1144·3

Brought forward .		1,120	1144·3
In its place there will be actually a coppice of 25 years under the shade of 120 2nd-rotation standards, and in which 120 new standards will be reserved. According to the working plan, 60 of the 2nd-rotation standards will be felled, retaining 60 for the next rotation. The sale will realise :			
Coppice	360 francs.		
60 standards at 2 francs	= 120	480	
Loss .		640	
Discounted for 65 years at 4 per cent. (ii) 640 × 0·0781			= 50
4. In 65 + 25 = 90 years there would have been a coupe worth		1,120	
We shall actually have a coppice in which, again, 120 new standards will be selected. The sale will realise :—			
Coppice . . .	310 francs.		
60 2nd-rotation standards at 2 . . .	= 120		
50 3rd-rotation standards at 10 . .	= 500	930	
Loss .		190	
Discounted for 90 years at 4 per cent.: (ii) 190 × 0·0293			= 5·57
5. Finally, at the next felling at 90 + 25 = 115 years, the normal condition will have been re-established and the full revenue will be realised. Therefore, the total loss amounts to . .			= 1199·87
Deduct salvage, say .			310
Net indemnity .			889·87

Commentary.

The anxiety to take into account all sylvicultural facts is perhaps praiseworthy, nevertheless, it is to be feared that it offers opportunities for controversy and is likely to prolong transactions to interminable lengths.

The method is cited here rather on account of its academical interest, and the following adverse arguments may be noted.

1. If the overwood is not in excess its canopy will not cause much harm. If, on the other hand, it is in excess, it

will kill out the coppice below it, which will not then be in a condition to supply substitutes for the standards removed, at least not for some time. It is, therefore, only the coppice adjoining the area beneath the standard canopy that will benefit and the gain will be inconsiderable.

2. The estimate of the value of more or less shaded coppice is speculative and arbitrary as one can practically never find types for comparison in analogous conditions in the vicinity.

3. It is generally admitted that under normal conditions the branches of a standard correspond approximately to the coppice growth which might occupy its place. Consequently, in calculating the volume of the standards it is only necessary to omit the crowns; therefore, if the trunks alone, that is to say, that portion fit for timber, are taken into account, the objection should disappear.

4. Most authors add to the depreciation the full actual value of the wood burnt—in the particular instance 414 francs—and that is what was done in the example quoted. The tests in Sections 64, 65 and 66 have shown that this award gives the injured owner more than the amount his coupes would have brought in; it is therefore unjust.

84. Increment of the standards after the removal of the coppice.—When either the upper or the lower storey in coppice-with-standards is damaged by fire without the other being injured, the *rate of interest for the whole area may no longer apply to the portion affected.* Such growing-stocks may indeed be considered to be composed of two separate exploitations: the one of a growing-stock—the coppice, the other of single stems—the overwood. Should one of the two escape all injury it would seem that it should undergo no modification, provided that the date fixed by the working plan for its exploitation remains unaltered.

It will be interesting to study the facts more deeply in order to ascertain whether this is invariably the case.

We have already discussed the subject as far as the coppice is concerned, let us now do the like for the standards. Not only is the upper storey important on account of its value, but also as it suffers less from fire it will be more often the survivor.

The felling removes the competition of the coppice for at least a few years, and the stems left standing are in undisputed enjoyment of a larger share of water and mineral elements. Circulation of air is also no longer impeded and

decomposition of the humus goes on more rapidly. Finally, the isolation of the stems stimulates the cambium to greater activity.

M. Schaeffer has proved that a simple cleaning causes a markedly improved growth. M. E. Mer obtained similar results after thinning. The experiments of both investigators, however, were conducted with too small a number of trees and in plots too disseminated, that is to say, the measurements were not sufficiently numerous to serve as a basis for definite and constant laws. As the result of a large number of experiments under all conditions MM. Friedrich and Böhmerlé, the most diligent observers on the results of opening out the canopy, are fully convinced that "in studying the laws of growth the most minute and scrupulous precautions must be taken to obtain trustworthy results."

No sooner did the question of the influence of felling on the trees left standing assume prominence, than, with remarkable sylvicultural intuition, M. Camond propounded the theory of the inverse ratio of diameter development, *i.e.*, greater near the crown while the standards are embowered in coppice, and *vice versâ* when freed. This hypothesis has been confirmed by the most recent scientific researches. The alternations of development tend to give an impression of rapid growth immediately after the cutting of the coppice, for, instead of measuring the mean diameter of the annual layers, the sole criterion of the volume increment, it is usually only the thickness of annual rings at breast height or on stumps that is taken.

Dr. Endres was the first to record rational measurements, but he also operated with an insufficient number of trees and limited himself to a single coupe. This forms also the sole objection to the remarkable detailed analyses offered by MM. Bartet, Henry and Mer. Not so favourably situated as their German colleagues, with scanty leisure and funds at their disposal, they have, nevertheless, greatly advanced our knowledge in this direction. In default of proper assistance, however, they have been unable to examine a large number of individuals of different ages, varying species and grown under diverse conditions of climate, aspect and soil. We must therefore agree with M. Böhmerlé when he says: "Such experiments are too restricted and it would be hazardous to draw definite conclusions from them."

Moreover, experts are very far from being in agreement regarding the benefit to the standards, at least with some species. Measurements effected at the Carlsruhe School under the supervision of Weise, have shown that, in the case of the ash, the greater development at the base of the bole is at least counterbalanced by a corresponding falling off above.

Similar results have been obtained with beech in certain regions, whereas measurements taken by M. Henry lead to an opposite conclusion. Two newly selected standards of that species retained when felling showed increased growth throughout the length of the bole, from the collum to the crown. Such tests, however, "do not conform to the general conditions essential for the formulation of a law."

Even M. Bartet's more sustained experiments do not permit us to come to definite conclusions; as pointed out by M. Màthey, the only two oaks which clearly benefited by the second isolation were precisely the ones that later on suffered most from the crowding of the undergrowth, as if the removal of the latter had only momentarily stimulated the growing-force to correspondingly relax it subsequently.

In spite of the discrepancies in these limited observations, M. Mer has been able to evolve, from the facts as a whole, the single positive general principle. "The felling of the coppice results in reduced height-growth of the standards, and the concentration of ligneous increment in the lower portions of the bole."

The greater development of the foot of the tree emphasises the conical shape of the bole, which amounts to a malformation and diminishes its value.

This is contrary to the usual vegetative process. Ordinarily, the crown exercises so powerful an attraction on the nutritive substances that it is first served and yields to the rest of the tree practically only the excess which it is unable to make use of, both as regards hydrocarbons as well as nitrogenous compounds.

Following on coppicing, if the standards evolve a greater quantity of proteids near the ground, we may agree with M. Mer in believing that the cambium may be so stimulated by the excessive nutriment sent up by the roots, that the attraction becomes greater at the foot than in the crown, and is enabled to draw from the latter its accumulation of

starch, a considerable portion of which could not in any case be utilised, owing to the insufficient supply of nitrogenous material. Without committing himself to so positive a declaration, R. Hartig attributes the excessive cellular development at the base to the coincidence of the descending flow of glycose with the abundance of mineral substances rising from the roots. This is the explanation of the hypertrophy which is to be observed in burrs, around wounds, in geotropic curvatures, dormant buds, and in the turgescence adjoining constricted impoverished layers which result from it. Now fires, even when not intense, dry up the cambium to a certain extent. Its vitality impaired it is incapable of profiting by the surplus nourishment. Any extraordinary increment is therefore prevented. Consequently, a fire is not beneficial but rather the reverse to the growing-stock remaining undestroyed.

In fine, in a regular forest, if there actually is an extraordinary increment, no one can venture to fix a definite proportion under all conditions.

The theory of "the balance of growth," advocated by M. Camend and defined by M. Mathey, will probably be opposed to the above hypothesis. It advances the reduction of increment in one portion of the tree in favour of another. The latest experiments carried out in France confirm these views: The new shoots of a standard of two or three rotations recently isolated, are shorter; consequently, M. Mer thinks it probable that they manufacture less starch, which inclines him to believe in a diminished supply of hydrocarbons, and in the long run, a "balance of nourishment."

As to fires, they appear to exert a deleterious effect on the girth development of standards. We are therefore in no way authorized to make any allowance in the indemnity for any presumed increase in volume.

85. Destruction of either the coppice or the overwood only in coppice-with-standards.—The absolute separation and relative independence of the two storeys being established, a separate and distinct calculation must be made in respect of the coppice and the overwood. According as the fire has affected one storey or the other, we are left with a simple coppice or isolated standards. Conforming with the invariable rule, the first step is to ascertain the rate of interest. Indeed, the coppice operates under one rate, the younger standards under another and the older under a third; the resultant of all three is the

ruling one for the growing-stock as a whole. First the actual area occupied by the coppice rootstocks (*ensouchement*) must be determined; for "to neglect the capital invested, which should be added to the value of the trees or coppice-shoots, would amount to confusing the rate of increment with the rate of interest." (*Broillard.*)

In order to ascertain the area occupied by each storey, observations must be made, not on adjoining areas, but in the very parcelle under enquiry, and that without delay for, as has been demonstrated by M. Watier, the crowns of the standards freed from the coppice rapidly expand, even up to three times their former area.

In the example selected (that of Section 44) the overwood covers one-third of the total area. Consequently, the *ensouchement* of the coppice alone is $\frac{2}{3} \times 220 = 147$ francs, and its share of the soil value *plus* the charges is :

$$\tfrac{2}{3}(150 + 65) = 143 \text{ francs.}$$

Its absolute estimation is calculated thus—

Soil . . .	143	francs.
Ensouchement .	147	,,
Capital invested .	290	,,
Revenue at 25 years	250	,,
	540	,,

Rate of interest . $290\,(1+x)^{25} = 540$

Whence . . $x = 2{\cdot}51$ per cent. or $2\frac{1}{2}$ per cent.

The estimation of the indemnity is then carried out in the manner described in Chapter I of this part. The absolute estimation for the overwood is calculated similarly. An example will be found in Appendix D.

III.

Damage to rootstocks.

86. Scorching of rootstocks.—A certain number of rootstocks are at times vitally injured. They are enumerated according to species. When the ruined stocks are few and far apart and not under the cover of standards, they are dealt with individually and the value of the trees they would have produced is estimated in agreement with the process for standards in section 67.

When, however, the damage is extensive and the burnt rootstocks are disadvantageously situated with respect to

standing trees, the aggregate space they occupied is ascertained either directly or by means of sample plots.

The loss comprises: 1, the cost of artificial restocking; 2, the failure of coppice regeneration on the area; the latter is calculated after the method described under the head of "coppice" or "coppice-with-standards" according to the sylvicultural system. When the rootstocks have not been killed, but the tissues have been sufficiently disorganised to cause depreciation of vegetative power, allowance for this must be made. It must not be forgotten also that artificial regeneration gives rise to weaker growing-stocks than those arising naturally. The difference of productivity is estimated either as an annuity or proportionately to the total final yield, or in some other manner; and is then discounted to date.

An example will be found in Appendix D.

IV.

Fire in cleaned coppice.

87. Efficacy of cleanings in coppice.—Like that of an isolated tree, the life-history of coppice is simple. The regeneration is effected by shoots and to a certain extent from seed; the re-growth springs up of itself, demanding no care. At the end of the rotation the coupe is felled, and it then reproduces itself, and so on indefinitely. Where there are standards, marking every 25 or 30 years is necessitated, and that is all.

Few proprietors give much attention to their woods between the fellings. Though the benefit of cleanings, both in regard to the growing-stock itself and from the financial aspect, has been amply proved in certain regions, it is exceptional for amateurs to practise them in their forests. Varenne de Fenille recommends them; Bagnéris gives them considerable space in his "Manuel de sylviculture;" MM. Gazin, Guinier and Détrie refer to them; M. Schaeffer has presented a thorough and complete monograph on the several operations included in cleanings: lopping, thinning out stool-shoots, cutting out inferior species and removal of twigs.

In these forests there are two fellings, the principal one at the end and the other intermediate during the rotation. The intermediate exploitation may be fixed at various stages in the course of the rotation: in the middle, as in the oak

coppices of Ariège; when two-thirds have expired, as in the private forests of Franche-Conté treated under the Gurnaud method; or at some other period, for example, eight years before the final felling, as is the case in Haute-Savoie as well as in the Holme oak forests of the Gard.

Varying with the country, the owners and the workmen, these improvements may be restricted to the shrubby weeds and soft woods, to the principal species, or may embrace both classes. The intensity of the operation also varies greatly: from a simple freeing of the stems selected for the future standards to excessive opening out, as is done in certain regions of the South in order to preserve pasture for sheep.

It is not procumbent shoots alone that must be removed, but also all erect but weedy and malformed ones. A safe rule, which to a certain extent should also be the limit, is to avoid uncovering the soil so as to expose it to sun and wind. On soils apt to dry rapidly and on hot aspects, it is better to refrain altogether; similarly where labour is highly paid and small wood sells at a low price.

Carried out on too small a scale the operation is onerous. If done freely, though not to excess, it becomes remunerative and at the same time has a distinct beneficial influence on the vegetation of the selected seedlings which have been freed, and probably on that of the standards, if they exist.

A recent work advises against the removal of twigs, not, however, because the efficacy of the operation is contested, but on account of the great care it demands. It is indeed prudent to abstain if the operator is unskilled or if circumstances are unfavourable, and it is therefore advisable to warn foresters against an exaggerated application. The principle being correct, however, it would be deplorable to neglect it; and this is far from the intention of the most competent authorities who have written on the subject.

Indeed, a decision to "leave it to nature" would have far-reaching effects; it would straightway condemn all cultural research and block all progress. Moreover, M. Mer has refuted the conception, remarking: "Every forest operation exacts care and skill in execution, but skill guided by the spirit of observation and not by empiricism; it would be absurd to sacrifice the advantages afforded by a practice because executive difficulties have to be overcome. It is precisely for instruction in surmounting these difficulties that tuition in forest science is necessary.

Thinnings in coppice form one of the simplest of operations less delicate than the selection of stems for future standard and certainly far easier than thinnings in high forest."

The same timidity would also dictate the suppression of all such operations as the freeing of seedlings, pruning, thinnings preparatory to seeding fellings and certain other works of improvement of a like nature, under the pretext that "they are equivalent to an advance of capital, the return and interest of which will only be obtained after a long interval."

M. Mer, moreover, has furnished the best proof of the value of thinning-out stool-shoots by practising methodical experiments; the results showed an increase in material as well as a greater value per volume unit. In nine years the *thinned coppice yielded an excess of about one-half in wood and money over the unthinned control coppice,* in addition to the material sold at the time of thinning.

Even admitting that these figures may vary slightly for other species and under different conditions, there will still be a gain and the operation will be justified.

88. Damage in cleaned coppice.—As example let us take the case of a coppice of this description (*vide* Section 45) which has been destroyed by fire at the age of eleven. Normally a cleaning is carried out at 17 years, which yields 80 francs, and the final felling at 25 years returns 400 francs.

FIRST CASE: *with disorganisation of management.*

The circumstances of the forest do not permit of the final exploitation being deferred to the normal age of 25 years; depreciation of the growing stock or disorganisation of management must be taken into account when calculating the damage.

(1) The final felling would normally have taken place in 14 years and would have yielded 400 francs. Instead there will only be 1,500 faggots at 5 per 100 = 75 francs. The loss is therefore 400 − 75 = 325 which discounted at 3 per cent. becomes:

(ii)

325 × 0·6178	. . .	= 200·78
Carried over	.	200·78

Brought forward . 200·78

(2) The cleaning which should have been effected 6 years later will not be carried out as the coppice will only be 14 years old at that date. This loss of 80 francs must be discounted for 6 years.

$$\overset{\text{(ii)}}{80 \times 0{\cdot}8135} \quad . \quad . \quad . \quad = 65{\cdot}08$$

(3) Cost of cutting-back: 5 woodcutters at 3 francs . . . . = 15

TOTAL LOSS . =280·86

(4) Deduct salvage . . . . = 25

Indemnity . 255·86

Verification.—Omitting the cost of cutting-back and the value of the salvage, the compensation for actual loss is 265·86 francs. Put out at compound interest for the balance of 14 years to the end of the normal rotation, this sum will become:

$$\left.\begin{array}{ll} \overset{\text{(i)}}{265{\cdot}86 \times 1{\cdot}6187} \quad . \quad . \quad . \quad . & = 430{\cdot}34 \\ \text{The wood obtained from the felling} & \\ \quad \text{at 14 years of age will be worth .} & \quad 75 \end{array}\right\} 505{\cdot}34 \text{ francs.}$$

In the absence of the fire the owner would have realised at that date—

$$\left.\begin{array}{ll} \text{(1) The revenue derived from the} & \\ \quad \text{final felling . . .} & 400 \\ \text{(2) The revenue derived from the} & \\ \quad \text{cleaning—80 francs, together} & \\ \quad \text{with interest on that sum for} & \\ \quad \text{8 years:} & \\ \qquad \overset{\text{(i)}}{80 \times 1{\cdot}3168} \quad . & = 105{\cdot}34 \end{array}\right\} 505{\cdot}34 \text{ francs.}$$

He would therefore be fully compensated financially.

Had the same fire occurred in the same coppice at 17 years of age, just after the cleaning, the following reasoning would be adopted.

At the normal date of the final felling the coppice will be only 8 years old and too young for cutting; it will therefore be left standing till the end of the next rotation. The growth will now be 33 years old and will fetch 720 francs.

The cleaning will still be carried out at the 17th year yielding 80 francs—

(1) Normally, in 8 years there would have been a felling giving 400; that sum at compound interest would, at the end of the second rotation, amount to—

(i) $400 \times 2{\cdot}363$ . .	$= 945{\cdot}29$
(2) In $8+25$ years there would have been a second final felling yielding . . .	400
(3) In $8+17$ years there would have been a cleaning felling yielding 80 francs, which at compound interest to the end of the second rotation would amount to— (i) $80 \times 1{\cdot}3168$ . .	$= 105{\cdot}34$
	1,450·54 francs.

Which corresponds to an actual immediate capital of—

(ii) $1{,}450{\cdot}54 \times 0{\cdot}3213$. $= 466$ francs.

Owing to the conflagration there will actually be—

(1) In 17 years a cleaning worth 80 francs, worth now—

(ii) $80 \times 0{\cdot}557$. $= 44{\cdot}56$

(2) In 33 years a felling yielding 720 francs, now worth—

(ii) $720 \times 0{\cdot}3213$. $=231{\cdot}34$

Together: 275·90 francs.

The loss is therefore 466—275·90 . .	=190·10 francs.
Add—Cost of cutting back: 20 days woodcutters' wages at 3 francs . .	= 60
	250·1 francs.
Deduct—Salvage	100
Net Indemnity .	150·10 francs.

Second case. ***Without disorganisation of management.***

Where there is no disorganisation it is merely necessary to calculate the value of the growing-stock by means of the general formula—

$$C = V\frac{(1+t)^{n-i+m}}{(1+t)^n - 1}$$

and by the methods of Section 56. Section 110 gives an example. In the case of fire at 11 years of age the solution is—

IV. Method—

$$\frac{80\times 1{\cdot}035^{\,25-17+11}+400\times 1{\cdot}035^{11}}{1{\cdot}035^{25}-1}-370=170{\cdot}80 \text{ francs.}$$

V. Method—(*Corrected.*)

$$\frac{80(1{\cdot}035^{19}-1{\cdot}035^{8})+400\,(1{\cdot}035^{11}-1}{1{\cdot}035^{25}-1}$$

$$=\left[80\ (\overset{(i)}{1{\cdot}922}-\overset{(i)}{1{\cdot}317})+400\ \times\overset{(i)}{0{\cdot}46}\right]\overset{(iii)}{0{\cdot}7335}=170{\cdot}50 \text{ francs.}$$

M. Broilliard advocates another method. The cleaning producing 80 francs swollen by its compound interest for 8 years (the period to lapse before the end of the rotation), then amounts to:—

$$80\times\overset{(i)}{1{\cdot}3168}=105{\cdot}30 \text{ francs.}$$

The capital producing 105·30 francs every 25 years is—

$$105{\cdot}3\times\overset{(iii)}{0{\cdot}7335}=77{\cdot}24 \text{ francs.}$$

Accumulated for 11 years (the age of the growing-stock at the time of the fire) it becomes—

$$77{\cdot}24\times\overset{(i)}{0{\cdot}46}\ .\quad .\ =\ 35{\cdot}5$$

The corresponding value for the final felling is—

$$400\times\overset{(i)}{0{\cdot}46}\times\overset{(iii)}{0{\cdot}7335}\quad .\ =135$$

170·50 francs.

M. Hüffel by another argument arrives at the same result.

Final felling.—The damage done is calculated as before—

$$400\times\overset{(i)}{0{\cdot}46}\times\overset{(iii)}{0{\cdot}7335}\quad .\ .\ .\ .\ .\ =135$$

Cleaning.—In 17 years it yields 80 francs, it should have fallen due 11 years earlier but for the fire—

$$80\times\overset{(i)}{1{\cdot}46}=116{\cdot}80$$

This loss at the present moment is—

$$116{\cdot}8-80=36{\cdot}8$$

Carried forward . 135

Brought forward . 135

Which sum will recur every 25 years, the damage, therefore, is equivalent to the sum of all these losses discounted to the present date :—

$$36{\cdot}8\left[\frac{1}{1{\cdot}035^{17}}+\frac{1}{1{\cdot}035^{17+25}}+\frac{1}{1{\cdot}035^{17+25+25}}+\dots\right]$$

$$=36{\cdot}8\left[\frac{\frac{1}{1{\cdot}035^{17}}}{1-\frac{1}{1{\cdot}035^{25}}}\right]=36{\cdot}8\,\frac{1{\cdot}035^{8}}{1{\cdot}035^{25}-1}=36{\cdot}8\times\overset{(i)}{1{\cdot}317}\times\overset{(iii)}{0{\cdot}733}$$

$$=35{\cdot}5$$

Francs 170·50

The separation of the cleaning from the final felling is fictitious and is here adopted for the sake of convenience and clarity ; it would be imprudent to carry it too far. Actually, these fellings, both intermediate and final, appertain to the same capital and are intimately connected. A simple formula must comprise them all and it is only under that condition that the average rate of interest derived from economic analysis may be applied.

V.

Fire in high-forest.

1. General.

89. Intricacy of exploitations in high-forest.—The first symptoms of the multiplicity of operations which follow upon each other in the treatment of high-forest, are revealed by the intermediate fellings in coppice, as we have just studied them.

In high-forest, a few years after the natural regeneration or replanting cleanings begin ; several thinnings at varying dates succeed ; terminating with either the extraction of mature trees, seeding, secondary and final fellings, or clean-felling coupled with artificial regeneration.

90. Destruction of a few individuals.—The methods employed in previous sections are generally applicable to broad-leaved high-forest and to shady coniferous forests (spruce) which never burn as a whole, that is to say, only scattered individual trees are destroyed. It is then sufficient if each tree is considered separately, the age, date of exploitability and price being known, and to discount the value to date.

91. Destruction of the whole growing-stock.—The value and individual importance of each tree cannot be estimated.—The situation is altered when the disaster is on a large scale and has affected a considerable portion of the growing-stock, as often happens in pine woods. These are usually established on permeable soil apt to become overheated owing to the open nature of the forest; a dense undergrowth of bushy shrubs and herbaceous plants is generally present, which renders the area highly inflammable at certain seasons.

In forests of this description the results of fire are disastrous, and the whole growing may be destroyed. In such cases estimation by individual trees is no longer possible; we are faced by an exaggeratedly confused aggregate made up of thousands of individuals differing in dimension, sylvicultural action and price.

"Every growing-stock, considered as a whole, has its individual particular development, the phases of which are complex and as yet ill-defined; its aggregate evolution is, moreover, a very different process from that of isolated trees". (*M. M. Canon & Gazin*).

It follows that it is not the single stem that is to be dealt with but the growing-stock as a whole, of which the value at all periods must be known. Pine woods are most subject to serious damage by fire and, therefore, deserve special study; a detailed analysis of such growing stocks will be met with further on.

92. Necessity of an analysis of the economic conditions of the exploitations.—In order to draw deductions respecting a whole forest, the conditions of working must be thoroughly known; they depend upon soil, climate, markets, prices, in short on so many local causes that one cannot generalise. All that has been said hitherto on the subject of coppice or isolated trees applies to all regions; all that was necessary in order that it should be admissible everywhere, was to change the figures of two items of the data: the yield in material and the price per unit. Here, too, the conception is of universal application, but in practice so many points making for divergence, the outgrowth of eminently variable cultural circumstances, are met with, that it is impossible to particularise. If it is desired to obtain exact data for a coupe, a definite growing stock must be considered and the prices must be calculated according to the results of actual working in that or adjoin-

ing forests; for no law governing the yield of thinnings has yet been evolved.

2. Pine Forests.

93. Paucity of monographs on French pine forests.—In France there are but few pine forests treated with a view to the yield of timber; few monographs, especially on the Scotch pine, have been compiled; the short notes published on the subject still leave much to be desired. M. Hüffel has commented on this point in his notable work,* from which we will, in due course, quote many passages relating to foreign countries. "In France, hitherto, the law of formation of the volume and the value of trees and growing-stocks (especially the latter) seems to have been but little studied; at least our contemporary forest literature shows scant traces of research in this direction. No doubt this is due to the fact that pure, even-aged forests, the only ones we will consider, are comparatively rare in our country. Nevertheless, the pioneers in this direction in the 18th century were Frenchmen: Réaumur, Buffon, Duhamel de Perthuis, Varenne de Fenille. They have had, however, but few followers in their footsteps during the last century."

94. Analysis of the pine forests of the Haute-Marne.—In the East of France there exist no pine woods that have been under regular treatment for several rotations. No working plans have undergone the test of experience; the fellings have been carried out irregularly as a special measure or at the pleasure of the owner. Nevertheless, in spite of the complexity of the question arising from the insufficiency of data and the absence of records, the analyst will not find disorder. There exploitations have been based on principles and have only lacked firm guidance and continuity. Failing written rules, we have collated the established customs; the comparison shows their concordance as a whole: the same plantations, conversions and period of exploitations. The sole points of disparity lie in the age and recurrence of the improvement fellings. The appraiser is within his competence in amalgamating these local methods into a general regulation. Though he is not in order in introducing modifications as he pleases, he may select the one local custom conforming most closely with sound

* "Les arbres et les peuplements forestiers."

sylvicultural notions. Moreover, it is not here question of change but of assimilation.

Our experiments were first designed to determine the phenomena of vegetation, and later embraced whole growing-stocks to ascertain their development and evolve appropriate working plans. The experiments were carried out on 476 stems in 22 sample plots scattered over 9 forests, under suitable treatment and average conditions. The heights, both total as well as up to the highest point yielding timber, were measured by the dendrometer and amply checked; the girths were taken at a height of 1·3 metres. The girths at the upper parts of the boles, and therefore the taper were obtained during the frequent fellings in these areas. The detailed tabular statements compiled from these measurements are lengthy and tedious; we need only reproduce the necessary columns: the average volumes and number of trees. The results are applicable to the Scotch pine high-forests of the Haute-Marne on calcareous oolite; but probably they may be extended with little divergence to similar soils, that is to say, poor and superficial ones, such as those of M. Mathey's 5th group.* In other countries the ages and prices will probably vary, since they are influenced by the soil, markets, means of transport, etc., the method however remains the same, it will only be necessary to introduce fresh units as basis. In the most dissimilar cases a few measurements will suffice to ascertain the new coefficients.

95. Material in an average pinewood.—Let us examine an area of one hectare containing 6,000 Scotch pine at its origin or within a few years thereafter. A larger number of plants needlessly increases the cost of planting and that of the first thinnings. Five thousand suffice in localities which are not too unfavourable, that is to say, when one has not, as in Haute-Marne, to fear casualties amounting to half and at times even to three quarters of the seedlings.

This reduction in the numbers customarily adopted is highly approved by M. Broilliard: "In plantations (of spruce and *à fortiori* of pines) the spacing of the plants must be in accordance with the object sought to be obtained....If telegraph posts or small building-timber exploitable in 60 years are required, 5,000 plants per hectare will be sufficient." These are our conditions in the present instance.

* Revue des Eaux et Forests, 15 Nov., 1 and 15 Dec. 1898.

According to the enumerations, the following table shows the progressive steps of the material :—

Composition of an average pinewood in Haute-Marne.

Ages.	Number of trees.	Trees removed when thinning.	Sundry casualties outside fellings.
At origin . .	10,000		$\frac{2}{5}$: 4,000
„ 12 years .	6,000	$\frac{1}{5}$: 1,200	$\frac{1}{10}$: 480
„ 20 „ .	4,320	$\frac{1}{5}$: 860	$\frac{1}{13}$: 270
„ 28 „ .	3,190	$\frac{1}{5}$: 630	$\frac{1}{17}$: 150
„ 36 „ .	2,410	$\frac{1}{4}$: 600	$\frac{1}{20}$: 90
„ 44 „ .	1,720	$\frac{1}{4}$: 430	$\frac{1}{20}$: 60
„ 52 „ .	1,230	$\frac{1}{4}$: 310	$\frac{1}{20}$: 48
„ 60 „ .	872	the whole 872	

For the reasons expressed in Section 106, the rotation is fixed at 60 years. As space will not permit of the inclusion of all ages from 1 to 60 years, those only are quoted at which fellings take place according to Sections 102 and 103.

The thinnings must be carried out exclusively with a view to cultural requirements; all systematic data and enumeration of trees to be removed or to be left, must be rejected. Indeed, that experienced sylviculturist M. Cannon, while adhering strictly to a judicious freeing of the crowns, found himself unconsciously led to a regular spacing, dependent on size and age, which forms the guiding principle of M. Gazin. The same idea is expressed by "suitable spacing" and "freeing necessary for each selected stem." Operating independently either ideal will lead to the numbers stated later on, which is not the *aim* but the *result*. This is proved by enumeration.

Were one sure of obtaining a sale for all trees which die in the interval between two thinnings, they could be credited equally between the coupe preceding and that following their disappearance. This would have the merit of obviating the further complication of adding the proceeds of casualties to the thinnings which already are sufficiently numerous. But contingencies must be provided for: accidents, incursions of insects, the great fall in price of pine when their small size renders them fit only for fuel instead of more highly priced material. Finally, if the owner does

not reside near his forests, his agent may neglect these accidental yields. In short, so many causes contribute to prevent their being turned to advantage that it is as well to leave them out of account, to lapse to *profit and loss.*

It is interesting to note that towards the end of the rotation the number of trees left standing varies but little in the several regions, though existing under very different conditions. As an example, we will compare them with those found in the most contrasting climate : the *landes* of Gascony. Here a well-managed pine forest contains at the end of the rotation, usually fixed at 80 years, 250 trees per hectare. In the Haute-Marne, were it desirable to resort to so high a rotation, as the resultant of two counterbalancing circumstances : diminished mortality induced by the better aeration of the growing stock on the one hand and more accidental falls and casualties on the other, we should find the composition of the stock to follow the course set out in the subjoined table.

Ages.	Number of trees.	Trees removed when thinning.	Sundry casualties outside fellings.
60 years . .	872	$\frac{1}{4}$: 200	$\frac{1}{20}$: 32
68 ,, . .	620	$\frac{1}{4}$: 160	$\frac{1}{16}$: 30
76 ,, . .	430	$\frac{1}{4}$: 110	$\frac{1}{16}$: 30
80 ,, . .	300	whole : 300	

It must be noted that the maritime pines on the dunes are treated principally with a view to the yield of resin from their early youth ; they are therefore thinned as heavily as possible. Everything, with this species, seems to demand and to absorb light ; its crown is denser than that of its congener and it requires more sunlight to stimulate the production of resin, which forms its most important source of revenue. Consequently, more space is necessary to it than is required for the Scotch pine of colder regions.

96. Consistence and productiveness of German pine woods.—Before deducing a general rule from the improvements effected by certain proprietors, it is well to test the results. A comparison flattering to France appears when consulting the works of German authors, the only ones who have written abundantly on the subject of pine forests ;

among others, the statistics published by Dr. Schwappach, culled from research stations. The analyses of similar writings, drawn out by M. Hüffel, will be equally useful.

In perusing the tabulated statements for German forests one is struck at once by the density of the growing-stock. This disparity in stocking is due to some extent to the dissimilarity of climate and soil (sand and low-lying plain), but mainly to difference in treatment. We believe that for France this density would be an exaggeration. This agrees with the opinion of Varenne de Fenille who, in a masterly essay demonstrating the happy effect of thinnings, which had previously been recommended by Rostaing, voiced the following aphorism: "Overstocking high forest gives more trees but less wood." M. Mer's experiments have led to the same principle. "It is better, on a given area, to have a restricted number of vigorous trees than an abundance with impeded vegetation." Indeed, the volumes of French forests equal during their youth those of German forests of the same age; towards the exploitable age they become decidedly superior. The following examples will show the distribution and material of the two classes of growing stocks.

Ages.	Number of stems in the pine woods.		Volume per hectare in pine woods.			
			French (in the Haute-Marne).			German.
	French.	German.	Available.	Intermediate removals.	Total.	
			c. m.	c. m.	c. m.	c. m.
30 years .	2,410	4,160	151	92	243	158
40 " .	1,720	3,070	222	58	280	211
50 " .	1,230	2,120	289	88	377	255
60 " .	870	1,490	281	94	375	292

It must be remarked that whereas in Germany these figures are obtained from forests grown on deep soils, or at least under *average* conditions, in the Haute-Marne the localities are *poor* or *very poor*. In the latter region pine woods are relegated entirely to the worst soils, altogether superficial and almost on pure rock; in fact such as cannot support field crops, nor even other forest growth.

Thinnings.

97. Efficacy of thinnings.—Wherein then lies the superiority of the French yield? It is due solely to a better comprehension of the requirements of pines, essentially light-demanders, and consequently to the practice of *heavy thinnings which secures to each tree the best conditions* of light, air and nutrition.

The girth and the height increments are stimulated, resulting in a yield of better class material at an earlier age. "In this way, with a smaller invested capital, an improved revenue in quantity and quality is obtained. The relative importance of intermediate yields is increased, so that it may equal or even surpass the final yield; *the average rate of interest is thereby raised.*"*

The danger of insect invasion disappears or at least is lessened. The small openings made in the canopy enable conifers as well as broad-leaved seedlings to spring up and occupy the soil without interfering with the trees above, and themselves unhindered by the latter; that is to say, a gain of a quarter or even a third of the time required to produce exploitable timber. In conclusion, it prevents the development of epicormic branches on species predisposed to their formation. So far back as 1872, M. Mer verified the fact that these abnormal sap-extorters appear most abundantly on trees with thin crowns. This fact is confirmed by M. Détrie, whose measurements show the number of epicorms to be in inverse ratio to the amplitude of the crown.

The advantages of this treatment, both from the economical and the cultural points of view, have been sufficiently justified by authorities on the subject. Already in 1832, C. André wrote: "He who thins his forest rationally, has nothing to fear on account of wind; natural regeneration can be obtained at pleasure and in the manner desired."

Pines can ill support a crowded condition. Interlacing branches lose their leaves and soon dry off; the crowns instead of assuming a circular outline, become contracted. Should this unhealthy state continue, most of the crowns become deformed; the stems themselves contract diseases and the whole growing stock may so degenerate as to be incapable of attaining an advanced age or of producing large timber. To obviate this serious defect, the surest method and one the efficacy of which has now been demonstrated, is to be

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* Hüffel, loc. cit.

found in thinnings. Experiments have proved *the greater yield of an open forest over a dense crop in pine woods.*

M. Broilliard is not less decided on this point: "Pine woods require early thinning; failing this the trees languish. The thinnings must be continued up to the age of fertility (about 60 years)." Further, in recent writings, this master of sylviculture returns to the same theme, the perennial interest of which contrasts strangely with the apathetic indifference manifested towards it by the majority: "In pine forests a crowded condition must be avoided."

M. Canon, a practical forester who has met with great success in Sologne, attributes the high yield he has obtained from his pines to thinnings, begun early and frequently repeated. In 1901, the society of French agriculturists adjudged to his method the first place of honour in its decennial awards.

From a work on thinnings * incorporating the best from writings accumulated during a century, we extract: "In a tree which passes from a crowded into a freer state, the rate of volume increment rises, often very markedly so. It is not rare that it is even tripled for trees isolated during felling, which had hitherto grown under crowded conditions. Observations have been recorded more than once of areas in which one-third, or even more, of the standing crop could be removed without loss to the total annual increment. On this fact is based the practice of thinning as it has prevailed in France for over three centuries, and as it is now being introduced into Germany."

Bagnéris, and especially M. Boppe through his: "Traité de sylviculture" in 1889, have drawn the attention of German foresters to French methods, with which the latter have since experimented on all sides and will in all probability adopt. Already several of their authorities have extolled the system: "The development of a tree is influenced above all by the extent of air space available for it. The trees hut in in a growing-stock is hindered in the extension of its roots and its crown; its increment is consequently retarded. The want of space impedes its growth which soon declines." (*Wagener.*)

Where strong winds are to be feared the sole method of preventing windfalls is by *thinnings, which prepare the trees for an isolated condition* by strengthening their root systems. M. Reuss records the prescriptions laid down by a

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* Hüffel, loc. cit.

Marienberg Ranger, entrusted with the duty of imparting a knowledge of the operations in the working plans of Saxony to experts of the several States of Germany. They deserve special notice coming as they do from that centre of forest research brought into renown by Cotta; the advice of M. Fincke, supported by the approval of masters such as Pressler and Judeich, must be received with respect. He advises heavy thinnings to a width of 20 to 30 metres along boundaries exposed to gales, in order to promote the development of the crowns and thereby that of the roots, thus increasing the power of resistance of the trees. With the same object in view he recommends timely thinnings on the perimeter of each sequence of coupes (corresponding to our periodic blocks), or that they be surrounded at an early stage, by rides 10 to 40 metres wide. The mission of these marginal bands is to prepare the growing-stock for isolation, so that the edges may not suffer through sun or wind."

98. Superior increment due to thinnings.—The effect of density of stock is well illustrated by volume figures borrowed from M. Schuberg's work:

Increment of silver fir stems.

Density.	From 48 to 50 years.	From 51 to 60 years.	From 61 to 70 years.	From 71 to 80 years.
	c. m.	c. m.	c. m.	c. m.
Growing-stock open	0·121	0·151	0·174	0·176
Growing-stock very dense.	0·055	0·079	0·096	0·111

Now the pine requires even more space for its crown than the silver fir, and what is applicable to the latter is still more so to the former.

M. de Salisch, who evolved a method of thinning in young pine woods, experimented with it at the Eberswalde (Prussia) Forest School, at the invitation of the Director. From the very start, the sample plots established at that

station demonstrated irrefutably the beneficial result of thinnings.

Growing-stock.	Volume of wood over 0·20m. in girth.		Remarks.
	At time of thinning.	14 years after thinning.	
	c.m.	c.m.	
A. Oak high-forest .	201	260	Light thinning.
B. Do. .	146	206	Heavy " (The two plots are contiguous.)

The German practice was adopted, that is to say, light thinnings were restricted to the removal of dead trees or those clearly dying; heavy thinning included, in addition, those showing partially dead crowns. It will be seen, therefore, that the so-called *heavy* thinning of our neighbours is still so limited, that it would not amount to a thinning at all in the sense given to the word in France, since it does not touch the dominant crop. A real thinning would have yielded a much more decisive result. The experiment reported by M. Hüffel affords a proof: on one sample plot 358 Scotch pines, 29 years of age, were freed of every hindrance from all neighbours, whereas in the rest of the parcelle, adopting Hartig and Cotta's prescriptions, only dead, diseased, or dominated trees were extracted.

At the end of five years, the trees were compared with the same number of stems standing in the dense area. Their increment was 23 per cent. greater, that is to say, the thinning had benefited those trees whose crowns had been set free to the extent of 23 per cent.

Elsewhere, on good soils, this result has been much exceeded.

M. Borggreve quotes a Scotch pine crop, the yield of which was increased ninefold.

The following table, drawn from the working plan report of the Haguenau forest, affords striking evidence of

the influence of heavy thinnings on the rate of volume increment of Scotch pine :—

Ages.	Dense crop per 100.	Thinned crop per 100.
30 to 40 years	3	7
40 to 50	1·5	
50 to 60	1	3
60 to 80	0·4	1·2
80 to 100	0·2	1

This increment is not due to a mere exaggerated enlargement near the base of the stem amounting to a malformation, and favouring the volume at the expense of quality. M. Mer's measurements, confirming the observations of Varenne de Fenille and others, have shown that thinnings promote not only diameter but height increment. M. Chavegrin is equally positive : "It is believed that trees grown under crowded conditions are more rapidly drawn up and attain a greater length of bole. The error of this assumption has been long since revealed by research. In truth, trees of the same age growing in a dense crop are far behind those standing in rational freedom ; the greater the number of stems per unit of area, the more patent is their inferiority in height."

The experiments carried out with spruce have been repeated with similar results for pines. As remarked by M. Gazin, "*In trees suitably spaced, the height increment is proportionate to the diameter*, which latter is subserved by successive thinnings." From the result of systematic fellings, R. Hartig deduced that disencumbered pines put on a quite remarkable growth, even at an age of 130 years.

With spruce, much less light-demanding than the pine, M. Mer has verified that a thinned area produces about a third more than one left untouched.

Finally, we may again quote from M. Hüffel's "Arbres et peuplements forestiers" :

"Following on the removal, at a single operation, of two-thirds of its volume, a beech high-forest crop 80 years old, increased its annual increment from 3·78 to 4·73 cubic metres per hectare ; an advance of nearly one quarter.

In oak and beech compartments, the yield, compared with the timber standard at the beginning of the experiment 14 years before, amounted to :—

	Light thinning per cent.	Heavy thinning per cent.
For oak	43	73
„ beech	112	182

These figures are significant but would have been more

so had the heavy thinning removed part of the dominant crop, instead of being restricted to the extraction of stems already deformed and partly dead.

These figures, which have been carefully kept within moderate bounds, testify to the influence of thinnings on the yield of even-aged high-forest."

Identical results have been obtained in experiments started in the canton of Argovie in 1877, and carried on since 1888 by the Swiss Central Forest Research Station.

After the thinnings executed by M. Kraft, the average rate of production rose from 2·45 to 3·46 per cent.

MM. Friedrich and Böhmerlé have just published their researches, which are the most recent in this direction. For Austrian pine, the diameter increment depends on the degree of intensity of the thinnings; that is to say, it rose considerably after heavy thinnings and remained at a low figure for operations of a light nature. The height growth progressed on parallel lines; the trees with most space showed the greatest annual increment in length. Moreover, the greater girth development did not adversely affect the shape, seeing that the proportion between the diameters at the apex and the base of the trunk, which gives the form factor, was 0·84 for areas heavily worked over.

99. Increased revenue and rate of interest due to thinnings.—M. Hüffel declares that: Well-executed thinnings augment the proportion of the intermediate yield and of the branches. This occasions a fall in the money yield, but is compensated and more than counterbalanced by the increased value of the stem-timber, with a diameter 30 or even 50 per cent. in excess in thinned forests. As the value rises at least as the cube of the diameter, we may assert that, at the same age, the unit value of stems of a thinned forest is double that of boles from an unthinned area. It is obvious, therefore, that a sound operation may materially raise the rental. Its influence on the rate of interest is still greater, for the revenue increases at a greater ratio than the capital invested. One element is indeed immutable, that is the soil. Even should its other component (*the stock*) expand as much as the revenue, which is improbable, the rate would still rise. In fine, compared with a forest maintained in a closed condition, one suitably thinned yields:

(1) At least an equal, if not greater, volume of timber of larger dimensions; (2) a greater money revenue; (3) a better return on the money capital invested.

M. Wagener has demonstrated the relation between the money returns of compartments thinned according to the German system and identical ones thoroughly opened out.

Consistence of the crop.	Spruce of				Beech of 80 years.
	60 years.	70 years.	80 years.	90 years.	
	Fr.	Fr.	Fr.	Fr.	Fr.
Dense growing-stock .	95	106	116	125	59
Growing-stock heavily thinned.	119	130	137	143	93

100. The importance of thinnings to be insisted on in view of their desuetude.—Such foresters as have verified for themselves the beneficial results of thinnings, and who cannot conceive good management in their absence, will perhaps find our insistence on this subject superfluous, deeming it one that has received universal recognition. It is not, however, for those already convinced that this work has been written, but for the sake of the uninformed. Our arguments, supported by irrefutable observations in order to carry conviction to all minds and to persuade courts of justice in case of necessity, are only too necessary in view of the slow dissemination of all cultural notions. The delay in this direction contrasts strongly with the impetus towards education which characterises our epoch. Already one of our most esteemed experts (M. Broilliard), a populariser of forest topics, has endeavoured to place that science within the reach of all. He has collated known facts, so as to bring a knowledge of the forest into the public understanding and to eradicate false, incongruous and harmful conceptions. Few are the owners who trouble themselves with improvements in pole-woods of 25, 30 or even 40 years of age. The branches interlace and die; the poles yield no marketable produce at an age when they should be fit for telegraph poles, hop poles, pit props; all most remunerative. Such neglect is prejudicial not only to the private owners themselves but to the public good. These pine woods, managed by rote as if intended for insect nurseries, contaminate adjoining forest and retard the progress of sylviculture in the region. For if "the diffusion of knowledge is the first step towards success in the improvement of

forests," good example has ever been recognised as affording the most profitable lesson.

At first sight, these cultural developments appear to be foreign to our subject, they form, however, an indispensable foundation in those chapters in which they are broached. Indeed, the valuations have an object, and the figures employed in the calculations are legitimate only so long as the fellings to which they refer are justified.

The utility and details of exploitation, when they are carried out in such diverging fashion, or are entirely omitted by careless proprietors, must be proved. Our arguments will become superfluous only where uniformity prevails, and the operations are everywhere executed in an identical manner.

101. Consistence (degree of intensity) of thinnings.—The matter then is settled: thinnings will be effected sufficient in scope to set the crowns completely free, without, however, overstepping the limits of prudence. It is an axiom and inseparable obligation of the method so ably described by M. Broilliard. In the mild climate of the coast of Gascony, the damp heat of which, with the absence of hoar frost, affords such an advantage over the cold atmosphere of the East, the directing rule remains constant: *complete stand to be maintained, with a periodical opening out of the canopy.* Simply more air and light are given access in order to stimulate the increments.

M. Schaeffer made similar deductions from the experiments of MM. Friedrich and Böhmerlé in Austria: "Medium thinnings give the best results as regards total production in volume." This moderation will permit one to conform to the recommendation of the International Congress of Sylviculture of 1900: "All struggle between neighbouring stems must be avoided, for it is always at the expense of growth that it takes place. The formation of the stems of the prospective crop, in as large numbers as possible, must be assisted by gradual freeing, beginning at an early age. When they are formed they must be successively thinned out to enable them to develop their crowns and root-systems."

The very special treatment of dense forests does not entirely reject the uncontested advantages of the rule. There, too, the improvements derived from the establishment and maintenance of a definite density of stocking, midway between that of German forests and the open state, is

recognised. Until recent years, the owners of these pine woods opened out their crops to a wide spacing from the fortieth year; the tendency now-a-days is to preserve a denser stocking in order to sell for mine props those stems which used to be cut out earlier for cord wood. The density of their forests, therefore, is not very different from ours; we grow our pines somewhat closer together since they do not secrete resin hence the necessity for light is not so urgent; on the other hand, their mutual support is required as a protection against snow.

The degree of thinning varies with the species: with oak, for instance, considerable opening-out ensures good quality of timber; spruce, on the other hand, is best left in a natural condition, removing only damaged stems; in other words: "tending must ever be subordinated to the economic requirements, that is to say, to the production, for each species, of the most useful and profitable timber." (*Broilliard*)

With the same species the degree of thinning will still vary with the age, as advanced by R. Hartig: "With conifers the greatest volume and the finest timber are obtained through moderate thinnings at first, increased to heavy at a later age, care being taken to establish undergrowth." This same sequence had already been laid down a quarter of a century earlier by the distinguished directors of the Nancy Forest School. (*Lorentz and Parade.*)

As to the manner of execution, M. Béral advises: "Each tree must be considered in particular, in itself as well as in its surroundings, the soil and locality—in short its environment, guarding against preconceived notions." "The thinnings, above all, must be opportune, avoiding systematic or mathematical rigidity." (*Broilliard*).

102. Age at first thinning.—M. Cannon, who resides in a region of pine forests, affirms that thinnings are rarely begun sufficiently early. This delay is prejudicial to the welfare of the growing-stock; "The first thinnings must be executed without thought of the value of the produce extracted, the sole object being the future of the crop. After a certain age and after the crowns have assumed a tenuous character, one dares no longer operate largely as the trees are too weak to withstand the competition of their neighbours. They will continue to languish."

On physiological grounds M. Mer is led to "thin at an earlier date in order to preserve sufficient activity in the cambium." With silver fir and *à fortiori*, with pine,

"there is a very real advantage in the trees not being too crowded, and especially in their being properly distributed; they must, therefore, be prepared for it early, even before the age of 20 years."

Experiments convinced R. Hartig and M. Mer that "the higher increment caused by thinnings is proportionate to the amplitude of the crown." Consequently, it should be stimulated by early thinnings. In this too, the former heads of the Nancy school forestalled German science; "To insure the most propitious conditions in a pine wood, the first thinnings should occur as soon it reaches the thicket stage." (*Lorentz and Parade*).

Cleanings begin at 12 years in the pure oak forests of the Landes. In dense seedling crops of pine, M. Samanos recommends a start at 5 years. According to M. Broilliard: "thinning may become necessary at 10 years of age in crowded and uniform pine woods, such as result from artificial sowing or planting."

A review of the crops of our regions shows the desirability of effecting the first thinning at about the 12th year.

103. Periodicity of the thinnings.—Bagnéris asserts: "To obtain the full benefit of thinnings, they must be repeated whenever the crop becomes too crowded to allow of the normal expansion of the crowns; observation shows that they should be more frequent during the period of height growth, and that they should preferably occur after equal intervals, in general every 10 years up to the 70th year, more or less, according to species."

The production of wood is dependent on the leaf surface; this botanical conception prompts M. Mer to give the advice: "Thinnings must be repeated as soon as a fall in the annual increment is observed. By their execution at the proper moment, that is to say, with great frequency, not only is the advantage of all resulting accretion obtained earlier, but further, the activity of the cambium layer having been better preserved, this increment is of greater absolute value." M. Hüffel relies on specific requirements: "Such species as naturally form our forests, *e.g.*, the Scotch pine, lose recuperative power if dominated for a lengthy period." M. Guinier states: "The pine is impatient of cover; it demands to be well nigh isolated after a certain age, and consequently, requires thinnings at short intervals." Judicious and frequent thinnings constitute one of the principles of the Gurnaud system.

MM. Gazin and de Liocourt, dealing simultaneously with the same subject, agree to work frequently over the same area so as to extract only a little at each operation, and thus avoid all abrupt alterations in the development of the crop.

On the score of this tendency towards a diminished extraction during the first few operations, and desiring to increase their frequency and regularity, M. Violette declares: "The method of periodical thinnings is that best calculated to procure the maximum production of timber."

The largest and tallest pines are to be found in open spaces. The system of continual opening out is therefore specially adapted to their requirements.

M. Cannon's apothegm epitomoses the principle: "*The health, the life of the crop, lies in judicious, reiterated thinnings.*"

For the oaks of the Landes the thinnings recur at intervals of 5 or 6 years, which is rather frequent considering the vegetative conditions of that region. In pine woods, M. Samanos inclines to return at first every second year, and later every 3, 4 and 5 years; but he refers to the forests of the South West of France, growing in fertile soil and in a hot, moist atmosphere.

In the less favourable climate of Germany, R. Hartig also insists on frequent thinnings in order to maintain an extensive leaf surface, as on this depends the enhanced woody increment. On the cold Vosges mountains, M. Mer advises more frequent operations than are customary, every 6 or 8 years for example, with a view to maintaining the individuals of the future crop in a constant state of freedom.

M. Broilliard is in favour of the same periodicity: "The thinnings, to insure good and safe results, must be renewed frequently, at intervals of about 6, 8 or 10 years."

The conditions of growth of the pine woods of this region lead us to adopt a periodicity of 8 years.

Estimation of pine woods.

104. Estimation of material.—Volume.—In order to estimate the material of a pine forest such as that described in Section 95, it is divided into as many classes of saleable products as the local conditions indicate. The volume is calculated mathematically or, which comes to the same thing in the end, by means of established tables. There is, however, a dearth of reliable data as to the relation between the volumes of branch wood and bole for pine trees.

In the Haute-Marne, the total volume of a broad-leaved tree is obtained by calculating the volume of the trunk and adding for every cubic metre:

1 *stère* of fuel, of which { $\frac{1}{3}$ is wood of 2nd quality and $\frac{2}{3}$ charcoal wood

and 10 faggots.

This proportion is not applicable to pines, the crowns of which are smaller in proportion to the bole.

In Germany, Pressler has fixed the volume of the crown in the proportion the height of the clean bole bears to the total height of the tree.

Scotch pine.

Ratio of length of bole to total height.	Volume of crown per cubic metre of bole.
m.	c. m.
0·7	0·19
0·6	0·29
0·5	0·41
0·4	0·55
0·3	0·71

These figures refer to middle-aged trees at the usual period of exploitability; for very young trees the volume of the crown is proportionately greater, and the reverse holds good for old trees.

The latest records of Prussian research furnish more complete data, but, *a priori*, they cannot be applied to our pine forests. We have already spoken of the density of the growing-stocks in Germany; the crowded trees exhibit contracted crowns. In France, thanks to thinnings, the foliage descends to a lower point about the bole. Thus the adoption of Dr. Schwappach's tables in our forests is absolutely out of the question. Pressler's figures, on the other hand, are derived from trees with well-developed and almost complete crowns, and if not quite exact, are at least very proximate throughout. These latter figures possess the further advantage of simplicity and practical applicability during marking. Our pines, more isolated, possess more voluminous crowns, nevertheless, they remain analogous to those of the Professor of Tharandt. The calculation is simple, for in an even-aged forest all the trees of a compartment are more or

less of the same height. The following figures are derived from experiments in this direction in the Haute-Marne:

Ages.	Proportion of height of bole to total height.	Volume of crown (branch-wood, faggots) per cb. m. of bole (timber and fuel).	Equivalent of last column in faggots and *stères* of branch-wood.	
			Faggots.	Branch-wood.
		c.m.		st.
12 years	0	2·5	167	
20 „	0·15	2·1	140	
28 „	0·40	0·83	55	
36 „	0·55	0·52	21	0·37
44 „	0·60	0·45	16	0·37
52 „	0·65	0·38	11	0·39
60 „	0·65	0·05	8	0·40

105. Valuations.—When we come to money value, owing to the multiplicity of classes of a saleable materials, we find that the value increment depends on numerous factors. The increment curve is not regular but rises *per saltum*, owing to sudden rises in value per unit as the material passes from one class into the next, *e.g.* from faggot to charcoal-wood, or from fuel to timber.

The following figures are drawn from Puton's "Traité d'amenagement" for Pinus sylvestris in Central France:—

At 20 years of age the value per hectare is	450	francs.
30 „ „ „ „ „ „ „	900	
40 „ „ „ „ „ „ „	1,500	
50 „ „ „ „ „ „ „	2,600	
60 „ „ „ „ „ „ „	3,600	
70 „ „ „ „ „ „ „	5,000	
80 „ „ „ „ „ „ „	6,000	

successive increments are therefore:

From	20 to 30	years:	45	francs per annum
„	30 to 40	„	60	„ „
„	40 to 50	„	110	„ „
„	50 to 60	„	100	„ „
„	60 to 70	„	140	„ „
„	70 to 80	„	100	„ „

We find the maximum attained between 60 and 70 years.

According to Dr. Schwappach, in the vicinity of Berlin a Scotch pine forest increases annually by:

From	30 to 40	years:	72 francs.
,,	40 to 50	,,	55
,,	50 to 60	,,	68
,,	60 to 70	,,	65
,,	70 to 80	,,	108
,,	80 to 90	,,	82
,,	90 to 100	,,	96
,,	100 to 110	,,	116
,,	110 to 120	,,	109

Here we have two and even three maxima: at about 35, 75 and 105 years. These figures, however, are correct only for the period and the locality for which they are calculated, that is to say, on good soil, in forests in which timber is converted in a certain fashion and where the several classes of products are sold at prices which do not correspond with those of our region. The special commercial circumstances of the Haute-Marne bring pit props into the place of highest importance. This reduces the exploitable age and lowers the crucial period to about 60 years. The following discussion of ruling prices and method of conversion will demonstrate this.

106. Conversion and prices per unit.—In the Haute-Marne, at a moderate distance from the Marne and Soane canal and under normal conditions of transport, standing Scotch and Austrian pine (the latter somewhat less sought after) fit for mine props, that is to say, of girths of above 0·25m. and below 0·70m. under bark, fetch 8 francs and 6·65 francs per *stère* respectively. For trees above 0·70m. in circumference, now fit for fuel only, the value falls to 2·15 francs. For branches and tops and portions of stem-wood falling below 0·25m. in girth, the rate is only 0·75 francs. Thanks, therefore, to the abundant demand and the cheap transport from that region (canals) to the mines of the North and of Belgium, pines are exploited to the best advantage when they have reached the highest mean increment, between 50 and 70 years, but before a majority of the stems have surpassed a girth of 0·70m. below bark; this occurs at an age of about 60 years.

At about the same period, the maximum soil rental and rate of interest are attained, as calculated by M. Broilliard in his enquiry on commercial exploitability. It may, moreover,

be brought to notice that the commercial exploitability was found to be 65 years as the result of experiments on the increment of pines in a portion of the crown forests of Saxony. To this period is added a constant term of five years as a kind of reserve against errors and accidents. The excellent results obtained by the successors of Cotta are a guarantee of their skill in management. Moreover, the milder climate of France gives us an advantage of five years, further increased by at least as much by the succession of thinnings. Finally, at that age pines are sufficiently fertile to ensure natural regeneration.

Guided as they are by a speculative spirit and by personal interest to obtain the highest rental from their property, and uninfluenced by considerations of general interest, that is to say, economic exploitation, private owners are well founded in adopting a rotation of 60 years.

The market value of pines follows from this *résumé*. In a regular forest, as is the rule with this species, four-fifths of the timber may be reckoned as pit props at 12 francs per cubic metre free of bark. The remaining fifth is accepted as fashioned wood at 10 francs per cubic metre free of bark. The faggots are valueless and are left as a free gift to the workmen.

107. Classification of products.—Value of an average pine wood.—The exact value of the products yielded by these pine woods is attained by separating their components at the several ages: mine props, *stères* of fuel, faggots, etc., i.e., *saleable material of all descriptions, at the actual market rates.*

This classification, accurately made out by mensuration of the several parts of the trees, furnishes the appended table. The arrangement is not the conventional one, but it is convenient for our purpose; it is clear, complete and gives all details necessary for the present study.

Material and value of an average Haute-Marne pine forest.

Ages.	Number of stems extracted per hectare.	Volume of a single tree. Bole. Pit props below bark. Poles.	Volume of a single tree. Bole. Pit props below bark. Fashioned wood.	Volume of a single tree. Bole. Fuel. 1st quality below bark.	Volume of a single tree. Bole. Fuel. 2nd quality.	Volume of a single tree. Tops and branches.	Volume of a single tree. Faggots, 0·015 cb. m. per faggot.	Prices. Pit props. Poles.	Prices. Pit props. Fashioned wood.	Prices. Fuel. 1st.	Prices. Fuel. 2nd.	Prices. Branch-wood.	Prices. Faggots.	Value per Tree.	Value per Coupe in round figures.
		c. m.	c. m.	st.	st.	st.		c. m.	c. m.	st.	st.	st.			
Years.								Fr.	Fr.	Fr.	Fr.	Fr.		Fr.	Fr.
12	1,200	...	...	...	0·0045	...	0·5	12	10	2·15	0·75	0·75	Valueless.	0·0034	4
20	860	...	...	...	0·0123	...	0·9	...	...	...	...	...		0·0092	8
28	630	...	...	0·0151	0·0314	...	1·7	...	...	...	...	...		0·056	35
36	600	0·009	0·0039	0·0605	...	0·02	1·1	...	...	...	...	...		0·292	175
44	430	0·0816	0·0204	0·0305	...	0·045	2	...	...	...	...	...		1·283	552
52	310	0·1308	0·0327	0·0305	...	0·073	2	...	...	...	...	...		2·017	625
60	872	0·175	0·0437	0·0305	...	0·097	2	...	...	...	...	...		2·675	2,333

Factors of conversion $\begin{cases}\text{for fuel } 1{\cdot}5\\ \text{for tops and branches } 1{\cdot}8\end{cases}$

In some pine forests accessory products have to be brought to account, such as: heather, resin, buds and needles for extraction of balsamic oil or for *vegetable bristle.* Their valuation is indicated in Section 119.

108. Pine woods being capable of self-regeneration correspond to a periodic revenue.—A question demanding solution is as to whether a pine wood is capable of regenerating itself naturally or not. The answer will depend upon climate, soil and method and age of exploitation. The table to be employed will thereafter be determined, according as the revenue has to be considered as periodic, or, on the contrary, as not corresponding to a self-restoring capital. Unsuitable local conditions may preclude good natural regeneration, so that the species may eventually be ousted by indigenous and better adapted ones. This is often the case with pines. A deep layer of undecomposed needles, sometimes attaining a depth of ten inches, prevents fallen seeds from germinating, or even should germination occasionally take place, the radicles are unable to reach the soil. In such cases natural regeneration is never more than partial. As there is, however, almost invariably a certain amount of natural regeneration, the compensation in case of fire should not be swollen by the cost of complete artificial re-stocking. In the Haute-Marne natural regeneration is satisfactory, and trifling supplementary cultural operations, such as slight working of the soil and burning of grass, are sufficient to establish it. Moreover, though there be a small deficit in the number of pine trees, it is compensated by broad-leaved species—oak and beech—springing up spontaneously, and making up for the soil covering if not for the timber.

109. Re-stocking.—Creation and maintenance of pine woods.—Generally speaking, the cost of re-stocking is included in the term " Material " in the estimation of the productive capital. Here the regeneration being in part artificial, we may add to the capital invested the value of the natural regeneration (110 per hectare), and deduct from the revenue the cost of artificial regeneration recurring every 60 years, which also amounts to 110 francs.

The initial stocking of a pine wood should consist of a minimum of 5 to 6,000 three-year old transplants per hectare, at a gross cost of from 18 to 22 francs per 1,000. In view of the usual proportion of failures in the region, due to frost or drought during the first few years, the estimate of cost

should be doubled, and therefore, on the average, will amount to:

$$5{,}500 \times \frac{20}{1{,}000} \times 2 = 220 \text{ francs.}$$

Towards the end of the rotation the growing-stock, now 50 to 60 years old, will be sufficiently open to produce seedlings.

Experience has shown that the planting necessitated by failure of natural regeneration and by damage during final felling corresponds, in the aggregate, with the artificial regeneration of half the area. After each final felling, therefore, the expenditure per hectare will be:

$$5{,}500 \times \frac{20}{1{,}000} = 110 \text{ francs.}$$

A further point should here be taken into consideration. The growing-stock has borne seeds from its fiftieth year and at the time of felling the seedlings will be of varying ages, but all of them more than zero. This enhanced value is often by no means negligible. Let us take an example: we find after the final felling the natural regeneration on the area consists of 500 7-years old plants, 1,000 of 5 years and 1,500 of 3 years.

Taking the cost of artificial regeneration, the increase in value due to this gain in age at 5 per cent. is:

(i)

$$\left.\begin{array}{l} 500 \times \dfrac{20}{1{,}000} \times 0{\cdot}407 = 4{\cdot}07 \\ 1{,}000 \times \dfrac{20}{1{,}000} \times 0{\cdot}276 = 5{\cdot}52 \\ 1{,}500 \times \dfrac{20}{1{,}000} \times 0{\cdot}158 = 4{\cdot}74 \end{array}\right\} 14{\cdot}33 \text{ francs.}$$

From these ages of 7, 5, and 3 years, the age of transplants from nurseries (3 years) is not deducted as this is compensated for by the greater vigour and the greater certainty of natural seedlings.

Fire in a pine wood.

110. Destruction of the whole growing-stock.—As an example we will take the case of a pine wood similar to that considered in the last section, which is burnt over at 12 years of age. The analysis of the exploitation and the absolute estimation reveal the rate of interest as 5 per cent., the capital engaged as 293 francs, and the total revenue at 5,180 francs.

FIRST CASE.—*With disorganisation of management.*

All the pines in a small section of the coupe have perished. The rest of the coupe must be felled at the proper date fixed by the working plan, as the regulation dimensions of timber for pit props must not be exceeded. For the same reason, the felling of the stock to be recreated on the area burnt cannot be postponed till the end of the next rotation (48+60 years). Its age (48 years) at the end of the present rotation, moreover, will be sufficient to yield merchantable timber of the lowest class, and its value per unit will be but little less than that of 60 years old timber. Consequently, we are faced with *disorganisation of management.* This is the commonest case and the calculations will be effected in a manner analogous to that employed in Section 66.

1. *Depreciation.*—Owing to the fire 4,800 pines have disappeared; of these, 3,700 formed part of the eventual major crop. In 8 years' time 860 would have been extracted in a thinning realising 8 francs, or discounted to date:—

(ii)

$8 \times 0{\cdot}677 \quad . \quad . \quad = \quad 5{\cdot}40$ francs.

Similarly, in 16 and then in 24, 32, 40 and 48 years, the several following thinnings and the final felling would have yielded 630, then 600, 430, 310 and finally 872 trees, with a revenue of 35, 175, 552, 625 and 2,333 francs respectively. These sums discounted to date represent losses of:

(ii)

$$\left.\begin{array}{ll} 35 \times 0{\cdot}458 & -\ 16 \\ 175 \times 0{\cdot}31 & -\ 54{\cdot}3 \\ 552 \times 0{\cdot}21 & -115{\cdot}9 \\ 625 \times 0{\cdot}142 & -\ 88{\cdot}8 \\ {}^{*}(2{,}333-110)\,0{\cdot}0961 & -213{\cdot}6 \end{array}\right\} \quad 488{\cdot}60 \text{ francs.}$$

Carried forward 494 francs.

* This factor (2,333—110) allows for the expenditure necessary to replace the forest in a condition of reproduction by re-stocking under normal conditions, that is to say, when the forest is capable at the age of fertility to fully re-stock half the area by natural regeneration. This is permissible in view of the admitted rule that, as far as possible, the forest must be restored the conditions existing before the fire, without altering the system of management or the intentions of the owner. In this particular case it works harshly as far as the owner is concerned, as the deduction would mean a pure loss were the area converted to any other cultivation. His position is less favourable than that of the owner of a house destroyed by fire; the latter obtains the amount of his policy without any deduction relating to reconstruction or subsequent utilisation of his award.

No further calculations under this head are necessary beyond the period of 48 years, as after the final felling, with the exception of replanting half the area, the forest will have resumed its original constitution.

Brought forward 494

2. *Re-stocking.*—The owner will be compelled to effect two complete artificial regenerations. The first immediately to re-stock the area burnt over 220

The second in 48 years, as at that age a pine wood affords practically no regeneration, or in any case, it cannot subsist under the close canopy prevailing at that age. However, only half the cost should be added here as the other half has previously been dealt with (as explained in the footnote). This half cost (110 francs), however, will only be disbursed in 48 years, and corresponds at the present date to a sum of . . . .

(ii)

$110 \times 0{\cdot}0961 =$ . . . . 10·6

(Items 2 together: 230·60)

3. *Cutting back** . . . .

TOTAL 724·60 francs.

Deductions :

4. The sale of wood burnt 12

5. Thinnings will take place in 12, 20, 28, 36, 44 and 48 years, which will yield 4, 8, 35, 175, 552 and 2,079 francs. (This last value is obtained from the tables in Sections 95 and 107). After the thinning at 44 years of age, 1,290 pines remain; during the next 4 years $\frac{60}{2} = 30$ disappear. At 48 years there are 1·260 stems worth :

$$\frac{1{\cdot}283 + 2{\cdot}017}{2} = 1{\cdot}65 \text{ each}$$

(ii)

$$\left.\begin{aligned} 4 \times 0{\cdot}557 &= 2{\cdot}2 \\ 8 \times 0{\cdot}377 &= 3 \\ 35 \times 0{\cdot}255 &= 8{\cdot}9 \\ 175 \times 0{\cdot}173 &= 30{\cdot}25 \\ 552 \times 0{\cdot}117 &= 64{\cdot}6 \\ 2{,}079 \times 0{\cdot}0961 &= 199{\cdot}8 \end{aligned}\right\} \quad 308{\cdot}75$$

(Items 4 and 5 together: 320·75 francs.)

LOSS 403·85 francs.

Carried forward 403·85

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* In the present case there would be no cutting back, but it should be noted that at about the age of 40 underwood of broad-leaved species appears, which plays an important rôle in the introduction of oak into the growing-stock and in the protection of the soil in an open forest. Such cutting back would therefore have been allowed had the fire occurred after the 40th year of the rotation.

Brought forward .	403·85
If the advantage of the extra age and vitality of natural seedlings is admitted, as mentioned in the last section, amounting to a value of 14·33; this discounted to date must be added: (ii) 14·33 × 0·0961 . .	1·40
TOTAL DAMAGE	405·25 francs.

Verification.—From the above calculated indemnity deduct the cost of planting to be carried out at once, and, if necessary, the cost of cutting back:

$$403{\cdot}85 + 12 - 220 = 195{\cdot}85$$

This sum at compound interest for the remaining period of the rotation, *viz.*, 48 years, becomes:

195·85 × 10·4013 .	= 2,037·10 francs.
The thinnings, sold for 4, 8, 35, 175 and 552 francs respectively, in 12, 20, 28, 36 and 44 years, will be put out at compound interest for 36, 28, 20, 12 and 4 years, and become: (i) 4 × 5·792 23·2; 8 × 3·92 31·4; 35 × 2·653 92·9; 175 × 1·796 — 314·3; 552 × 1·215 — 670·7 =	1,132·50
At 48 years the recreated stock will be felled together with the rest of the coupe, and will then consist of 1,260 pines worth 1·65 francs each .	= 2,079
	5,248·60 francs.

Had no fire occurred, the owner would have had:

1. At the end of the rotation, *i.e.*, at the age of 60, a naturally regenerated stock worth: . . . 110 francs.
2. In 8 years a thinning worth . . 8 francs
   - 16 „ „ „ 35 „
   - 24 „ „ „ 175 „
   - 32 „ „ „ 552 „
   - 40 „ „ „ 625 „
   - 48 years a final felling worth 2,333 — 110 „

Carried over . 110 francs.

Brought forward . 110 francs.

These amounts put out at compound interest from the date of realisation for 40, 32, 24, 16 and 8 years respectively, would have become:

(i)	
8 × 7·04 = 56·3 . . .	
35 × 4·765 = 166·8 . . .	
175 × 3·225 = 564·4 . . .	. = 5,138·60 francs.
552 × 2·183 = 1,205 . . .	
625 × 1·477 = 923·1 . . .	
(2,333 − 110) = 2,223 . . .	
	5,248·60 francs.

The two totals are identical.

Complications may arise, as, for example, when the fire occurs in the middle of the rotation. In this case at the end of the normal rotation the replanted area will be too young; it will yield only fuel of small value, not even covering expenses. The felling will have to be postponed until the crop has reached the age of 40, that is to say, when it will yield timber of the lowest quality. Consequently, its second rotation will have to be shortened correspondingly, and it is only at the end of the latter that the *statu quo ante* will be reached. In this case the disorganisation of management will extend over two rotations; the calculations will be extended but will not entail additional difficulties. They will be carried out in a manner similar to that just expounded.

SECOND CASE.—*Without disorganisation of management.*

If the entire forest is burnt there is, strictly speaking, no disorganisation of management. Besides the actual material damage done, there remain to be taken into account only the vexation caused to the owner, the overthrow of his expectations, and considerations of a like order; these are conventional values and their estimation is dealt with in Sections 26 and 121.

The damage therefore can be calculated in accordance with the principles expressed in Section 64, and the practice laid down in Section 56.

Let us consider the same pine wood as in the last section, but entirely destroyed at the age of 44 years, that is to say, immediately after the completion of the fifth thinning.

We will apply the fourth method of Section 56, in which the capital value of the property is calculated by the formula

of intermediate fellings; and the capital invested is then deducted.

At m years the realised yield is :

$$\frac{V'(1+t)^{n-i'+m} + V''(1+t)^{n-i''+m} + \ldots + V(1+t)^{m}}{(1+t)^{n}-1} - F$$

Five thinnings at 12, 20, 28, 36 and 44 years having been effected, the co-efficient of the four first terms will be, m—i′, m—i″ etc., or in figures: 44—12=32, 44—20=24, 44—28=16, 44—36=8, 60—52+44=52, 60—60+44=44.

The fifth term is :

$$V^{v}\frac{1}{(1+t)^{n}-1}.$$

Then we get :

(i)		
4 × 4·765 =	19·1	
8 × 3·225 =	25·8	
35 × 2·183 =	76·4	
175 × 1·477 =	258·5	
552 × 1 =	552	
625 × 12·643 =	7,901·9	
(2,333—110) × 8·557 =	19,022·2	
	(iii)	
	27,855·9 × 0·05656 =	1,575·50 francs.
	Deduct—The capital invested	293 ,,
		1,282·50 francs.

1. The value of the wood burnt is :	1,282·50	
Add—		
2. Cost of re-stocking	220	francs.
3. Cost of cutting back the broad-leaved undergrowth, four days woodcutter's wages at 3 per day	12	,,
4. Value of natural regeneration (in this case the wood is too young and has no value)	...	
	1,514·50	francs.
Deduct—		
5. Amount of sale of burnt wood	1,241	,,
Compensation	273·50	francs.

Verification.—Omitting the cost of replanting and cutting back, as they are disbursed at once by the owner, the latter receives, partly from the sale of the burnt wood and partly as indemnity, the sum of 1,282·5 francs.

Put out at compound interest at 5 per cent. for 16 years this becomes:

$$\overset{\text{(i)}}{1{,}282{\cdot}5 \times 2{\cdot}183} = \qquad 2{,}799{\cdot}70 \text{ francs.}$$

In 16 years the regrown wood will be worth, to the owner who has no wish to part with the property:

$$\begin{array}{rrl} & \text{(i)} & \\ 4 \times & 1{\cdot}215 = & 4{\cdot}9 \\ 8 \times & 15{\cdot}367 = & 122{\cdot}9 \\ 35 \times & 10{\cdot}401 = & 364 \\ 175 \times & 7{\cdot}04 = & 1{,}232 \\ 552 \times & 4{\cdot}765 = & 2{,}630{\cdot}3 \\ 625 \times & 3{\cdot}225 = & 2{,}015{\cdot}6 \\ (2{,}333-110) \times & 2{\cdot}183 = & 4{,}852{\cdot}8 \end{array}$$

$$11{,}222{\cdot}5 \times \overset{\text{(iii)}}{0{\cdot}05656} = 634{\cdot}8$$

$$-\ 293$$

$$341{\cdot}8 \quad . \quad 341{\cdot}80 \text{ ,,}$$

In addition at 12 years there would have been a thinning producing 4 francs and this in 4 years becomes:

$$\overset{\text{(i)}}{4 \times 1{\cdot}215} = \quad . \quad 4{\cdot}90 \text{ ,,}$$

$$3{,}146{\cdot}40 \text{ francs.}$$

In the absence of the fire the owner would have realised:

1. A thinning yielding 625 francs, which at compound interest for 8 years would have become:

$$\overset{\text{(i)}}{625 \times 1{\cdot}4775} = 923{\cdot}4 \quad .$$

2. A final felling of $2{,}333 - 110 = 2{,}223$.

} 3,146·40 francs.

The two totals are identical.

Procedure of insurance companies.—In the pine wood under consideration, the inspectors of most insurance companies would not include any value for the stock of natural regeneration nor for the potential productive stocking (*ensouchement*) of broad-leaved growth, because they have not given rise to any special expenditure in creation, and because the second has not been destroyed. The characteristic features of the system of treatment are overlooked and an arbitrary rate of interest is adopted, generally 3 per cent. Several methods of estimation are in vogue but all are analogous to those previously considered. Let us study one of them further.

According to this system, as dealt with in Section 23, the proprietor will receive :

When the Fire occurs at 12 Years of Age.

First Hypothesis.—Natural regeneration disregarded.

1. Interest at 3 per cent. for 12 years on the value of the soil and cost of artificial regeneration— $*(60+110)\ (1{\cdot}426\overset{(i)}{}-1) =$ . .		72·40 francs.
2. Cost of re-stocking		220 „
		292·40 francs.
Deduct—		
1. Salvage	12 .	
2. Value of first thinning . . .	4 .	16 „
Compensation .		276·40 francs.

Second Hypothesis.—Natural regeneration allowed for.

Interest as before . $(60+110\times 2)\ (1{\cdot}426^{(i)}-1) =$.	119·30 francs.
2. Cost of re-stocking	220 „
	339·30 francs.
Deduct as before	16 „
Compensation .	323·30 francs.

With a rate of 5 per cent. the results become 339 and 427 respectively. The correct indemnity in the event of disorganisation of management, amounts to 403·85 francs.

In case of Fire at 44 Years.

First Hypothesis.—Natural regeneration disregarded.

1. Interest as before . $(60+110)\ (3{\cdot}671^{(i)}-1) =$.	454 francs.
2. Cost of re-stocking	220 „
3. Cutting back of broad-leaved undergrowth .	12 „
	686 francs.

* 60 francs is the value of the soil —*vide* Section 46.

Deduct.—The value of the four first thinnings put out at compound interest for 32, 24, 16 and 8 years, respectively—

(i)

$$\begin{aligned}4 \times 2{\cdot}575 &= 10{\cdot}3\\ 8 \times 2{\cdot}033 &= 16{\cdot}3\\ 35 \times 1{\cdot}605 &= 56{\cdot}2\\ 175 \times 1{\cdot}267 &= 221{\cdot}7\\ 552 \quad &= 552\\ & \quad 856{\cdot}5\end{aligned}$$

2. Salvage . . .	1,241	2,097·50 francs.

Which is a negative value, and we arrive at the absurd position of the owner being indebted to the company.

Second Hypothesis.—Natural regeneration allowed for—

(i)

1. Interest . (60+110×2) (3·671—1)=	.	748	francs.
2. Cost of re-stocking	.	220	,,
3. Cutting back	.	12	,,
		980	,,
Deduct as before	.	2,097·50	francs·

or still a minus compensation.

Even at a rate of 5 per cent. the results are possible with the second hypothesis only, and the owner will then receive 175 francs. But even without disorganisation of management the proprietor would be entitled to 273·50 francs. Therefore the system is in no case an equitable one without modifications.

111. Destruction of a small number of pines.—When the disaster is not complete and only a few trees are burnt, the estimation can be made as in Sections 67 and 77. This method, however, is open to some objection as the individual tree grown in a close crop does not follow the laws of growth of a single isolated tree; its development depends upon its environment; it also reacts on the surrounding stems and its rôle is difficult to define.

It is necessary, therefore, to base calculations on data applicable to a whole unit of area such as a hectare.

The first example of the last section gives a net indemnity of 403·85 francs for a fire occurring at 12 years of age. As there are 3,700 stems in the major crop, this gives an average of $\frac{403{\cdot}85}{3{,}700}=0{\cdot}1091$ francs per tree. Thus supplemented, the

valuation is correct since the rôle of a ***single*** tree in a thinning is not known ; it is the ***aggregate result***, in which each individual plays its part, that is perceptible. On the other hand, the figure given for salvage ***en block*** (12 francs) might be contested, as the damage can be appraised directly. It would be better to substitute $\frac{p}{x}$ for $\frac{12}{3,700}$, p being the sum of the estimated values of x pines destroyed, or better still their sale price. The actual value of the salvage is then deducted from the gross indemnity.

Fire in a Selection Forest.

112. Selection Forests.—This work treats in detail of regular, that is to say, even-aged forests only, because they form by far the larger proportion of those exposed to danger from fire, and because no precise method can be devised for irregular crops. Fir woods do not burn, at least, as a whole, and it is pine woods only that are liable to be seriously damaged (in France) and these are rarely worked under the selection system. In Provence, and perhaps there alone, are pines found predominating in mixed forests. In such forests when the individuals damaged are few and scattered, their value is calculated according to Section 67, accessory damages being included, more especially those connected with cultural depreciation, which may assume great importance in such cases.

If the area over which the damage extends is considerable, the estimation may be effected in several ways, according to the condition of the growing stock—

1.—*When the growing stock is normal.*—The proportion and distribution of age classes aimed at by the system of management is secured and each felling removes only the increment. The estimation of the indemnity is then identical with that described in detail for the pine woods of the Haute-Marne.

2.—*When the distribution is still imperfect.*—The stems composing the wood are not properly spaced. All the stems, excepting those of inferior species, present merely to make up the requisite density, are measured for comparison with the same growing stock arrived at the normal condition, that is to say with the ideal type selected, so organised that a sustained yield in quantity and quality is obtained. The appraiser when establishing this parallel must base his conclusions on the felling prescriptions laid down by the

management and directed towards the realisation of the ideal constitution. He will take into account the fact that the possibility, restricted by deficiency in certain classes, would be obtained mainly from those in excess.

Again, if the forest has not yet reached the degree of commercial exploitability desired by the owner, the period by the end of which this condition would have been attained must be calculated. M. Reuss indicates the method: "The yield V^1, V^2, V^3 . . . V^p will be estimated up to V, the normal annual yield. The total value will then be the resultant of these revenues discounted to date:

$$\frac{V^1}{(1+t)} + \frac{V^2}{(1+t)} + \quad . \quad . \quad . \quad . \quad . \quad + \frac{V^p}{(1+t)^p} + \frac{V}{0{\cdot}0t \times 1{\cdot}0t^p}$$

These calculations are of a delicate nature."

When the requisites for the ideal growing-stock are not present, that is to say, when there is no prescribed management, the valuation becomes a most difficult matter. One has then to deal with ill-managed woods, exploited haphazard at irregular intervals. No reliable data as to yield in material or in money are obtainable, and it will be necessary to ascertain the increment and the exploitability. If then the condition of the growing-stock is not too abnormal, M. Broilliard's recommendation may be applied: "In a selection forest, provided the growing-stock is complete, the production of wood is more or less constant. The annual revenue is at its maximum in relation to the capital invested when the maximum production is felled."

In any case, one must ascertain the number of exploitable trees which would be available in each rotation, in short, frame a plan of exploitation to remedy the shortcoming. It will, of course, be approximate only, but nevertheless preferable to a procedure consisting in classifying the trees into age classes presumed to reproduce themselves periodically, and estimating their values as for standards over coppice. No general rules can be laid down; but the main principles set forth in this study are always applicable.

VI.

Accessory Damages.

By accessory damages is meant those not directly affecting the woody material. Accessory damages may equal in value the indemnity for the actual wood, and in certain

cases even they constitute the only appreciable injury, as when a light fire destroys the dry leaves only.

DESTRUCTION OF THE SOIL-COVERING.

113. The effects of a Fire cannot be likened to those produced by the constant removal of the soil-covering.— The constant removal of soil-covering for agricultural purposes causes considerable injury to the forest and, according to several eminent authorities (Fabre, Hüffel Schwappach and Henry), may prejudice the increment up to 50 per cent.

A single accident cannot, however, be compared to this, as it were, persistent parasitism, which regularly deprives the forest of the whole humus. Apart from recurrence in the one case, however, the difference between the two is not so great as would at first appear. Certain influences of each predominate in turn but the eventual consequences are comparable.

Thus, the recurrent removal of its covering deprives the soil of its principal mineral constituents, more especially if aggravated by excessive grazing, whereas it would seem as if this were not the case with a fire. The extraordinarily vigorous growth following on the burning of herbaceous and semi-woody plants would, no doubt, tempt many people to a conclusion favourable to fires as stimulators of growth. This exuberance, however, is merely the effect of a temporary stimulus; it is not sustained, and is followed by a depression, which is the reverse of enhancement. Chemical decomposition in operation in the soil provides slowly, but surely and indefinitely, the organic products which the growing stock assimilates every year. The fire, however, at one operation, effects the transformation of the detritus and, so to speak, condenses by anticipation the small but certain interests into an immediately available capital, which stimulates for the moment, but rapidly disappears, leaving to the trees only a minute fraction. The greater portion, swept away by rain, flows into the subsoil out of reach of the absorbtive power of the enfeebled roots. In a very few years there remains no particle of the ashes, and as the soil covering has not had time to re-establish itself, the vegetation falls below its original condition.

In rare cases, where deep layers of arid soil overlie the subsoil, the products of combustion supply an excellent alkaline corrective. On the other hand, if the humus is scanty a fire is disastrous. In any case " fire is ever a dangerous auxiliary.

It renovates the weeds but for 4 or 5 years. The soil, already too poor and now further exhausted by the fire, will soon be re-covered with whortleberries (*Vaccinium*) and heather, more vigorous and noxious than ever" (*Mathey*).

Professor Flahault condemns the removal of the soil-covering because "it alters the conditions of the soil, which become highly unpropitious to sylviculture. The hygiene of the forest requires the maintenance of a cover for the soil and the preservation of its natural manure, the fallen leaves."

M. Ed. Blanc, as the result of exhaustive research on moorland soils, concludes that: "the removal of litter, deplorable and ruinous in all respects, is the principal, if not the only, cause hindering their improvement. Instead of being perpetually ameliorated under cover of forest by fertilising detritus, the soil is being constantly impoverished."

Ebermayer states: "Forest exploitation should not only preserve for the growing-stock its provision of nutritive materials, but still further increase them and bring fertility to arid soils, thanks mainly to the maintenance of the soil-covering which is the natural manure of the forest, and which, after conversion to humus, has an effect analogous to that of green manure in agriculture on the chemical and physical properties of the soil." M. Henry expresses the same opinion: "In forests where the soil covering is preserved the proportion of nitrogen goes on increasing, on the other hand, removal of litter reduces it rapidly. If repeated, the vegetation languishes for want of nitrogen." It is the leaves that assimilate the lion's share of the precious elements, the woody tissues demand but little. By analysis Dr. Ramann ascertained that the wood of broad-leaved trees absorbs barely 10 per cent., and that of conifers 15 to 30 per cent. of the materials taken up by the roots for their nourishment; the rest is appropriated by the leaves.

However abundant the minerals may be, plants cannot do without humus, which forms vegetal soil by admixture with the former. Humus is the last stage in the transformation of the débris which make up the dead soil-covering and of which leaves constitute two-thirds.

In agriculture the conservation or improvement of the quality of the soil is effected to a great extent mechanically, by ploughing and harrowing; in forestry, *per contra*, as a rule, neither cultivation nor manuring are carried out and other means come into play. Among the most potent is the action of microscopic vegetable organisms: bacteria or fungi.

So long back as 1862 Pasteur expressed the opinion that micro-organisms were the agents of nitrification. The absolute proof was supplied by Schloesing and Müntz. The principal aërobic agent of transformation in neutral soil was separated by Winogradsky. Van Tieghem brought to light an anaërobic bacillus playing an active part, not by oxydisation but by reduction. Higher organisms than bacteria exercising the same functions, are found among fungi with a filamentous mycelium; they ramify throughout the soil-covering, as revealed by Dr. Müller's researches. Eminent scientists (De Bary, Schwann, Schröter, Cohn, Hoffman . . .) have demonstrated that the formation of soil is a biological phenomenon caused by organic ferments. Other higher fungi actively decompose vegetable matter, reducing the constituents back to their mineral elements. These agencies are very complex, but must all be referred to the vital processes.

The constant removal of litter deprives the forest of their beneficial influence, by withdrawing the layer in which they swarm. Fires achieve the same result by killing off these lowly organised plants. They reproduce, on a large scale, the experiments of Wollny and of M. Henry, and arrive at the criterion suggested by Müntz: the prevention of all fermentation, concomitant with life, by means of anæsthetics or of heat. Indeed, they act more powerfully since ether, thymol, etc., or dessication at a temperature of 120° C., do not interfere with chemical fermentations (*diastases*) and do not transform the substance, whereas fire destroys it. An abnormal rise of temperature, more than any other means, accomplishes the death of organic bodies and more readily expels the carbonic acid gas held mechanically in the interstices; and it is this gas, both agent and product, which serves as a measure of the rate of decomposition of the leaves.

Even where they do not destroy the humus-forming bacteria, the flames lower their activity enormously by diminishing the humidity of the soil. According to Von Fodor, whereas soils containing the ones 17 per cent. and the others 8 per cent. of water, respectively allow 66 and 41 parts of carbonic acid gas to escape, when their percentage of water falls to 4 and 2, they emit only 24 and 2 parts of the gas. The proportion of gas is therefore as 1 to 33 against a difference of only 1 to 8½ for water. Wollny's figures agree with those of Von Fodor and confirm the fact that organic matter decomposes more rapidly when in a moist state. Similarly

the experiments of Schloesing and Dehérain on uncovered soils, such as in glades or areas denuded by fire, show that the production of nitrogen increases with the degree of humidity: "Nitrification is at a standstill in an absolutely dry soil."

We can trace out, therefore, the direct harmful effect of fire on the formation of humus, which is the source of all vegetation; its first results are the absolute dessication of the superficial layer and the destruction of the micro-organisms which are harboured by it.

Scrupulously accurate observations on the removal of soil-covering have been carried out in Prussia for over thirty years in diverse crops of beech, spruce and Scotch pine. Perhaps they cannot furnish accurate data of the total losses to which French species are exposed in our varying climates, nevertheless, it is quite certain, and is admitted on all sides, that in all forests the removal of the soil-covering has a most prejudicial effect, especially on poor soils. Though precise figures cannot be quoted in each case, the analogy of the German researches yields significant indication of values. If we take care not to exceed them, we shall guard ourselves against contradiction, while taking account of the loss experienced. We will study this loss according to the effect produced: chemical or physical. Its methodical study will disclose the several aspects of the subject, some little known but which it is important to lay stress upon. They refer to the disappearance of *dead leaves*, *grass*, *shrubby undergrowth*, and *earthworms*.

114. Dead Leaves.—Miscellaneous Débris.

Leaves.

If sufficiently intense to decompose the humus and the humic acid, the fire deprives the leaves of their power of increasing their store of nitrogenous compounds. Even when the fire runs rapidly over the surface without affecting woody growth the dead leaves are destroyed, and it has been clearly shown by M. Henry that these, excepting on pure sand, possess in a high degree the faculty of deriving nitrogen direct from the air.

After the discovery by Schloesing and Müntz, in 1877, of the chemical transformations caused by bacteria in the soil, the importance of research along this line in connection with agriculture led to the neglect of analogous studies within forest areas. The presence of nitrogen in the soil was ascribed exclusively to the action of more or less deep-seated micro-organisms. Professor Henry, at the Nancy Forest

School, demonstrated the chemical reaction of the dead leaves themselves, and his experiments in 1897 proved that they can double their original stock of nitrogen.

The mass of leaves produced annually per hectare will vary according to the quality of the soil, the climate, species, age, method of treatment, density of the growing-stock and the luxuriance of the crowns. It may attain to as much as 1,200 kilograms of green material. On this subject Bavarian research stations have supplied very interesting figures, but, as remarked by M. Henry, these are minima. "They apply to forests burdened with rights to litter. The impoverishment brought about by this abominable practice is reflected by the vegetation." Observations recorded in other countries add their corroboration. Jaeger and Buro, working under the same conditions, are in accord with Professor Ebermayer. On the other hand, on soils not subjected to exhaustion, Dr. Krutzsch verified an excess in weight of one quarter for spruce and one-seventh for Scotch pine. The excess for the latter species would have been the same had the experiment been extended to forests brought to a satisfactory state of light and aëration by suitable thinnings. Provided that the crop is not dense and light penetrates in sufficient quantity, M. Henry asserts that well-grown trees produce not only more, but larger leaves than individuals grown on poor soils. Sections 96 and 98 give an account of the density of German pine forests, and of the enormous additional increment produced by early and frequent thinnings in such crops. The truth of this fact, moreover, has been tested: within the boundaries of Bavaria, but under good cultural conditions, considerably higher yields have been obtained even than those derived from the sexennial collection (weight of all the organic débris fallen during six years and not yet transformed into humus).

Mean weight of soil-covering.

Crop.	Soils impoverished by rights to litter		Ordinary soils.
	Annual collection.	Sexennial collection.	
	Kgs.	Kgs.	Kgs.
Beech	4,107	8,460	10,417
Spruce	3,538	9,390	13,857
Scotch pine . . .	3,706	13,729	18,279

Finally, in countries such as ours, which enjoy a purer atmosphere and a greater total heat, the crowns are better developed.

M. Henry has confirmed these opinions by his researches on coppice and high-forest in France. Thus, in Lorraine, though it is one of the coldest of our provinces and one of those most subject to fogs, a fully developed beech forest yielded in one year double the weight recorded in Bavaria; that is to say, over 5,000 kgs. of leaves, nominally dried at 100° C., and over 8,000 kgs. of total dead soil-covering. These data enable us to draw up a tabular statement on the same plan as that laid down by the Director of the Bavarian stations. These experiments have not been carried out for all species, at varying altitudes and in diverse climates, therefore, figures can only be given with an approximate average, that is to say, subject to slight alterations under special conditions. Nevertheless, the possible discrepancies are limited, if we are to believe Ebermayer: "The difference between the quantity of leaves produced by the several forest species cannot be considerable." The figures arrived at apply to crops grown under normal conditions; they therefore exceed the yield from forests subject to rights to litter, *i.e.*, abnormal; they fall, however, below the maxima obtained in France as also in Germany. These moderate valuations appear to be applicable to the generality of cases and, consequently, to depart in the least possible degree from the truth. It is open to appraisers to adapt them to the peculiarities of the particular forest under their consideration.

Weight of dead soil-covering, completely air-dried, produced yearly per hectare, in high-forest.

Growing-stock.	Leaves.	Miscellaneous débris, living phanerogams excluded.	Total.	Remarks.
	Quint.	Quint.	Quint.	
Beech : 10 years . .	19	12	31	These quantities refer to crops, the regeneration of which is completely successful ; otherwise they must be reduced.
,, 20 ,, . .	30	13	43	
,, 30 ,, . .	39	20	59	
Beech : 40 to 60 years .	47	29	76	
,, 60 to 90 ,, .	46	28	74	The weight decreases with the age.
,, over 90 ,, .	45	28	73	
Oak : 10 years . .	14	10	24	
,, 20 ,, . .	23	11	34	
,, 30 ,, . .	29	18	47	For want of sufficient data the figures for oak are approximate only.
,, 40 to 60 years .	37	25	62	
,, 60 to 90 ,, .	36	24	60	
,, over 90 ,, .	35	25	60	
Hornbeam : 10 years .	19	12	31	The last remark applies to hornbeam also.
,, 20 ,, .	30	13	43	
,, 30 ,, .	37	20	57	
,, 40 to 60 years	42	27	69	
,, 60 to 90 ,,	40	26	66	
,, over 90 ,,	36	28	64	
Scotch pine: 20 to 25 years	34	22	56	The weights increase with the age.
,, 50 to 75 ,,	35	23	58	
,, 75 to 100 ,,	40	30	70	

"In coppice with standards the weight of the soil-covering rises progressively up to the tenth year; thereafter it remains practically constant until the next felling, averaging 5,500 kilogrammes of dry substance for soils and growing-stocks such as those of the forest of Haye" (*Henry*). Of this quantity of débris the leaves form from one-third to three-quarters.

The following statement presents the weights ascertained at the ages of 1, 20 and 30 years; those at 6 and 10 years have been deduced from the totals of leaves and dead twigs which are known accurately.

Weight of the dead soil-covering produced annually per hectare in a mixed oak, hornbeam and beech coppice-with-standard.

Ages.	Dry soil (Oolite).			Clayey soil.		
	Leaves.	Miscellaneous débris, living phanerogams excluded.	Totals.	Leaves.	Débris.	Total.
	Quintaux.	Quintaux.	Quintaux.	Quin.	Quin.	Quin.
1 year .	6	15	21	...	...	...
6 years .	20	24	44	...	...	..
10 „ .	34	23	57	...	...	...
20 „ .	39	13	52	28	18	46
30 „ .	31	24	55	...	...	...

To give greater force to the argument, M. Henry has assumed the most unfavourable conditions, omitting the soluble ammoniated compounds, nitrates or starch which may have been formed to disappear with the water. His weighings showed that a year after their fall, 100 kgs. of oak and hornbeam leaves presented a maximum gain in nitrogen of 0·666 kg. The leaves have lost their colour by then but not their shape, and are still by no means reduced to humus. Their capacity for fixing the gas is diminished, but does not entirely cease until they are completely decomposed, which requires about 3 years for many species (beech) and

may take double that time for the reduction of the needles of conifers. Thus, if we accept 0·85 kg. as the quantity of nitrogen fixed by 100 kgs. of leaves we shall be well within the mark, even after making full allowance for such quantities as may be given off as gas during the course of the various processes of decomposition of organic substances. This figure indicates only the actual gain or increment in nitrogen achieved by the leaves after their fall. At the time of their fall the leaves of course already contain nitrogen in quantities varying with the species. The following table gives the figures adapted from the analyses of MM. Fliche, Grandeau and Henry:—

Species.	Albuminous contents of dead leaves. (November.)	Corresponding weight of nitrogen per 100 kgs. of dead leaves.
	Per cent.	Kgs.
Beech	7·81	1·250
Oak	6·62	1·060
Scotch pine	11·81	1·890
Birch	3	0·480
Chestnut	3·75	0·600
Larch	5·50	0·880
Spruce	8·43	1·350

In the principal species we see that the quantity of nitrogen exceeds 1 per cent., and we may accept this as the minimum for oak, beech and hornbeam. For these three species, therefore, the total loss in nitrogen caused by fire is at least 1·850 kg. per quintal (100 kgs.) of soil-covering destroyed. For pine trees it is probably 2·50 kgs., but in the absence of sufficient data it will be safer to accept 2 kgs.

Débris.

Dead twigs, fruits, fragments of bark, and débris of all kinds, that fall to the ground, are capable of yielding nitrogen to the soil. Decomposition may be slow in many

cases, but eventually they are invariably reduced to substances suitable for assimilation by plants (starch, ammoniacal salts, nitrates). Now a fire, however light, destroys these tissues and liberates the nitrogen which forms 0·7 per cent. of the bulk. Under normal conditions the nitrogen, obtained in the two ways described, would go to form the ulmic substances of the soil, and in that form would remain incorporated in it. It is volatilised by fire, however, and is lost to the forest. The money loss occasioned corresponds, therefore, to the cost of manure containing an equivalent bulk of that element. This price varies (in France), according to locality and description of manure, from 1·5 to 1·85 francs per kg. of mineral nitrogen. Farm manure, which raises its price to 2·5 francs, is too costly. As for the products drawn directly from the atmosphere by Messrs. Bradley and Lovejoy, they have not yet established their validity.

Tables of valuation can now be drawn out according to the kind of manure selected and its market rate, giving the money equivalent of the dead soil-covering. Thus, should the soil be clayey, nitrate of soda would be applied, as that has been found a most suitable form of fertiliser. Taking the percentage of nitrogen to be 15, and the price 24·75 francs per quintal, 1 kg. of the element will cost 1·65 francs. Now, in a fully stocked 100 years old beech forest, it has been calculated that there are, per hectare, 4,500 kgs. of fallen leaves and 2,800 kgs. of débris, representing 83·25 and 19·6 kgs. of nitrogen respectively; the indemnity for the loss of the soil-covering in this case should therefore be 169·70 francs. Similarly, in a pine wood 40 years of age, the needles amount to 3,400 kgs. and the débris to 2,200, corresponding, respectively, to 68 and 15·4 kgs. of nitrogen; and the indemnity amounts to 137·6 francs. Again, in a 6-year old coppice-with-standards, the leaves account for 37 kgs. of nitrogen and the débris for 16·8 kgs.; consequently, the amount of the compensation would be 88·75 francs. These figures exclude the cost of transport and spreading of the manure.

Some of the manures thus applied to compensate for the nitrogen withdrawn, yield other fertilising constituents, but this should furnish no pretext for any deduction from the indemnity payable. Indeed, mineral elements are not interchangeable; tree-growth, though less exacting than agricultural crops, nevertheless demands as urgently the presence of certain indispensable substances and they suffer

immediately these fail or are present in insufficient quantities. It follows, therefore, that the additional compounds found in artificial manure may not necessarily compensate the loss of the soil-covering; moreover, these fertilisers, specially selected to meet agricultural requirements, are not invariably equally beneficial to forest crops. These latter demand nitrogen, and the person responsible for the fire is at liberty to supply it in any form whatever, since plants assimilate it in diverse combinations. The following conditions, however, must be complied with always: the quantity of nitrogen replaced must be within one per cent.—*the fertiliser must be suitable to the soil.* Nitrate of soda must be restricted to clay and stiff soils, for in too permeable a one its extreme tendency to vertical diffusion would cause it to sink into the substrata, out of the reach of the roots. Sulphate of ammonia (20 per cent. of nitrogen) is suitable for more porous soils or those of a calcareous nature. For light, stony and gravelly soils, organic manures will be preferred, such as stable manure (4 per cent. nitrogen), dried blood (11 per cent.), oil cake (4 to 5 per cent.), chips and shavings, horn-scrapings and hair (14 to 15 per cent.)

Further, the season must be taken into consideration. In spring and summer, when the roots are most vigorous, a rapidly acting substance may be employed, whereas in winter or during rainy weather one of a more stable composition will be preferable.

The proportion of nitrogen contained in the leaf varies at the different periods of its life; it is less at the time of its fall from the tree, and then rises by absorption from the atmosphere. It would appear, therefore, that the date of its combustion should also enter into the calculation, but this would only be necessary when two fires occurred on the same area within a period of one or two years, that is to say, at a less interval than is required for the complete decomposition of the carpet of débris, as in that case the cycle is interrupted. Thus, should the leaves be destroyed a little before they reach their greatest activity, the forest is robbed of the results of the work they would have achieved; but had the fire occurred three months later, they would not yet have yielded up all the nitrogen elaborated and the soil would not have been enriched in the same proportion as the leaves. It is the actual increase of nitrogen in the soil and not its fixation by the leaves which is the important point,

and this is effected imperceptibly and in all probability with great regularity.

115. Grass. Heather.—"Herbaceous weeds that spring up in young coupes, drawing their nourishment from the humus, return to the latter and enrich the soil. Dehérain has shown that this adventitious vegetation, owing to its action in arresting the dissolution of nitrogenous compounds, is very efficient in maintaining the fertility of soils." (Mathey). In a growing forest, it is true, there is no loss of nitrogen by drainage, as it is only in the form of nitrates that it is washed down into the lower strata ; and in soils in which the humus is exclusively of vegetable origin, nitrification does not go on, or at least only on a very limited scale. This fact, foreshadowed by Boussingault, has been demonstrated beyond question by the experiments of Ebermayer, Bréal and Henry. But here we have not to consider the condition of full productivity. The soil is laid bare by a fire which destroys the soil-covering and dominant crop, or at least seriously impairs its vitality. The same holds good during the first years of a growing-stock, when it is still incomplete. At this period nitrification may still take place and the rôle of the thin growth of weeds, which appears principally on blanks, is to seize upon the salts. Possibly the weeds may even enrich the soil, as woods abound in leguminous plants, and Hellriegel and Wilfarth have established the important action of the root-tubercles of members of that family in fixing free nitrogen from the air. M. Mathès of Eisenach proved the influence of this phenomenon on growing-stocks of various descriptions: thus trees growing in association with acacias more than doubled their dimensions owing to the beneficial action of the latter species.

Finally, thanks to Schloesing, we know that by maintaining the surface soil sufficiently moist grass enables it to derive nitrogen from the air.

Under unfavourable conditions these functions are probably but slightly active, and we may even concede that the volume of nitrogen drawn from the atmosphere and from suspension in water does not exceed that set free during the decomposition of organic substances, in short, there is no increase. Still the fact remains that the burning of the grass destroys a store of valuable elements, and some loss must result.

In order to estimate the value of this herbage, M. Mathey in his valuable work—"Forest pasture" (*Pâturage en forêt*), expresses it in terms of the price of fodder. Ours, however, is a different standpoint and we must look upon any such transaction with abhorence as an unsylvicultural expedient. On the other hand, to admit grazing in the forest would be still more objectionable and could not be permitted in a well-managed property, tending as it does towards denudation. Still, for the sake of information and completeness, these valuations will appear in the tables annexed.

It would seem that the problem can be satisfactorily solved only by chemical analysis, and, indeed, more than one scientific agriculturist has delivered himself of the opinion that ultimately the exact value of forage will be appraised according to its chemical composition.

Forest grass when dried makes a poor quality of hay. According to Wolff's analysis it contains :—

	Per cent.
Water	14·3
Cellulose (ligneous products)	33·5
Non-nitrogenous products	38·2
Fatty oils	1·5
Mineral ash	5·0
Proteids (nitrogenous compounds, starch, nitrates)	7·5

This proportion of protein, however, is a minimum of rare occurrence and Schloesing raises the figure to 12·62 per cent., but it must be admitted that he referred to aftermath of meadow land much superior to forest grass. For the commoner species of sylvan and meadow grasses Joulie assigns 1·46 to 1·89 per cent. of nitrogen, but he included the roots and it would be an exceptionally intense fire that burnt the underground portions. An examination of the various figures quoted above allows us to fix 8·5 per cent. as the average proportion of protein.

All these substances are decomposed by combustion. The volatile elements are set free in the form of gas; a loss not to be neglected. However, as none of them are in demand as fertilisers and as we have no other way of estimating their value than according to their nutritive worth, they will be left out of account. There remains on the ground the 5 per cent. of mineral ash, composed of phosphoric acid and alkalis (potassium, lime and magnesium). The albuminous

constituents (8·5 per cent. of protein) alone constitute the loss of fertilising materials. On an average, they contain 16 per cent. of nitrogen; thus 100 kgs. of forest grass contain 16 × 0·085=1·36 kg. of nitrogen.

The following table gives M. Mathey's determination of the yield of dry hay per hectare in a dense coppice:—

Age of the coupe.	Calcareous soils.		Clayey soils.		Siliceous soils.	
	Yield in kg.	Net value.	Yield in kg.	Net value.	Yield in kg.	Net value.
	Kg.	Fr.	Kg.	Fr.	Kg.	Fr.
1 year . .	...	...	...	...	...	...
2 years . .	1,500	36	2,000	40	2,500	40
3 „ . .	500	12	1,500	30	1,800	28·8
4 „ . .	300	7·2	1,000	20	1,400	22·4
5 „ . .	250	6	700	14	1,100	17·6
6 „ . .	200	4·8	400	8	800	12·8
7 „ . .	150	3·6	200	4	600	9·6
8 „ . .	125	3	150	3	400	6·4
9 „ . .	100	2·4	125	2·5	200	3·2
10 „ . .	90	2·16	110	2·2	150	2·4
11 „ . .	80	1·92	100	2	125	2
12 „ . .	70	1·68	90	1·8	110	1·76
13 „ . .	60	1·44	80	1·6	100	1·60

Below 100 kgs. the value is insignificant.

During the first few years following on the felling, small blanks, major rides, lines and paths bear a considerable crop of herbs; but as the crop grows its shade extends, the blanks contract and fallen leaves and moss prevent the sprouting of grass. M. Mathey, therefore, estimates the

production of dry fodder per hectare on small blanks in coppice under a 25 years' rotation as follows :—

Calcareous soils.				Clayey soils.				Siliceous soils.			
Yield in kg.			Average net value.	Yield in kg.			Average net value.	Yield in kg.			Average net value.
Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.	
Kg.	Kg.	Kg.	Fr.	Kg.	Kg.	Kg.	Fr.	Kg.	Kg.	Kg.	Fr.
During the first years after the exploitation.											
1,500	1,000	1,250	50	2,000	1,500	1,750	52·5	2,500	2,000	2,250	67·5
During the last few years.											
250	100	175	7	375	150	260	7·8	500	200	350	10·5
In the middle of the rotation.											
500	150	325	13	750	250	500	15	1,000	300	650	19·5

Therefore, a fire in a dense coppice 6 years old on calcareous soil, would cause a loss of 1,000 kgs. of hay containing $2 \times 1{\cdot}36 = 2{\cdot}72$ kgs. of nitrogen. At the rate of 23·5 francs per 100 kgs. of 13 per cent. manure, the loss amounts to $2{\cdot}72 \times 1{\cdot}8 = 4{\cdot}9$ francs.

Heather. Moss.—Where the heather and moss are found on the forest floor their valuation is easy. Even where they do not extend throughout the area they at least grow rank in patches of considerable extent, the area of which can readily be estimated, and the weight per unit of area be calculated by actual weighment on sample plots.

Their composition is analysed by Dankelmann : 100 kgs. of air-dried heather and moss contain respectively 1·250 and 1·400 kgs. of nitrogen, worth, at the rate of 1·80 franc per 500 kgs., 2·25 francs for heather and 2·52 francs for the moss.

116. Physical and cultural results of the loss of soil-covering.—The *physical properties of the soil-covering* are not given due importance. Under this head must be included various prejudicial effects of fire on forests. They are often neglected, either through ignorance or for want of data for the expression of their values in figures; this,

however, does not detract from their importance, which is often considerable. As M. Van Schermbeck has said: "From the moment the results of scientific research were put into practical use, agricultural science embraced the physical functions of the soil in as large a measure as its chemical reaction."

Now, the rôle of the litter of dead leaves and fragments is not only to produce nitrogen and yield up the mineral elements it has obtained from the geological subsoil; its offices are multifarious.

Its *power of imbibution* varies according to its composition; on an average it can absorb three times its own weight of water. Dr. Krutzsch raised this figure for beech to 4·5; whereas Colas, experimenting under natural conditions, that is to say, with a loose and uncompressed carpet of leaves such as is actually found on the forest floor, attributed a far greater power to its hygrometric capacity, up to nine times in the case of oak. Saturated with moisture, it allows water to filter away from it drop by drop only, and it offers a stubborn resistance to evaporation from the surface layers, maintaining that degree of humidity, the absence of which involves weakening or even cessation of chemical action. In places where the soil covering is preserved, the degree of moisture in the soil is 20 per cent. greater than where it has been removed. This difference was determined in the neighbourhood of Frankfort on the Oder, and would be greater still in countries with a higher temperature. The importance of this fact cannot be overestimated when the function of moisture in the soil (too often insufficient in quantity) in relation to vegetation is understood. Until demonstrated by these recent experiments its exact value was not correctly appreciated, owing to the fact that its weight in proportion to that of dry soil, instead of its actual volume, the true factor, was taken into consideration.

Soil-covering checks extremes of temperature.

Its protective effects in regard to denudation and inundations will be dealt with further on; at this stage we must restrict ourselves to its influence on the fertility of the soil and on the welfare of the growing-stock.

On bare soil of a clayey nature heavy falls of rain beat down and consolidate the superficial layers, forming a hard impenetrable crust through which rain and gases cannot permeate, thus impeding the development of vegetation. In friable soils, on the other hand, the finer particles of

nutritious substances are carried mechanically by water into the substrata, where they are lost to the roots which are left with but the large and unprofitable pieces. In the forest the carpet of dead materials tempers the impact of heavy rain and preserves the physical properties of the soil.

Fire, though slight and innocuous as regards the principal growing-stock, almost always destroys or at least injures the more or less woody, low plants, such as holly, brambles, heather, etc., which form a secondary cover to the soil. Generally, damage from such fires is said to be *nil* because no importance is attached to this undergrowth, whereas it is invariably useful and often indispensable. Its presence is favourable to the accumulation of fallen leaves and débris which go to increase the humus. Its shelter ensures the freshness that encourages vegetation, and is essential for the gradual and regular decomposition of the soil-covering. It prevents the transformation into turf of certain rank grasses, the roots of which are apt to form a matted layer that dries up the soil and obstructs the infiltration of light rain. Finally, it has been shown that these suffrutescent plants yield to the soil more nutriment than they extract from it. The crowns of old oaks have been observed to revive after shrubs had grown up around their feet.

M. Ed. Blanc quotes in the following words a saying of the people of the Landes, who can hardly be accused of either much love for forests or scrupulous respect for their conservation: "They have observed that in an open state the production of the soil is incomplete; especially have they noticed that the soil does not improve or become more fertile, as would be the case if an uninterrupted vegetation covered it with a grateful shade and preserved its accumulation of dead leaves comparatively fresh; they would then contribute a fertile manure, whereas in the usual state of affairs three quarters are burnt up by the sun."

Ebermayer has drawn attention to the influence of shelter in the following terms: "The ground is well shaded and the air maintained tranquil, which conditions prevent the drying of the superficial layers of the soil, the abrupt and dangerous variations in the degree of humidity and the evaporation of surface water. The dead soil-covering, the humus and moss, absorb rain and snow-water like a sponge and assist its infiltration into the soil; they keep the underlying rock moist and preserve it from rigorous cold, from denudation and from erosion."

Borel measured growing-stocks that had experienced abnormal meteorological conditions, and concluded that: "Excessive heat and prolonged drought invariably diminish the production of wood. The best protection is a complete canopy, which ensures the soil against dessication. . . . The undergrowth and the soil-covering, both living (grass and moss) and dead (leaves), must be carefully preserved."

These remarks are of a very general character and are almost universally applicable to forests. But all localities have not the same needs; where marshes or water basins without outlet occur, it is sun and aëration, auxiliaries of drainage, that are required, and not shade, which assists the formation of peat. However, permanently saturated blanks are exceptional.

The cultural rôle is not of less importance; brambles, thorns, holly, etc., assist in the success of natural regeneration, especially in the germination of acorns; to seeds of other species a similar service is rendered by other kinds of shrubs. The natural regeneration of timber trees is poor in woods destitute of undergrowth; the smallest bushes even collaborate actively in reafforestation by virtue of the protection they afford to seedlings. According to Dr. Schwappach, natural regeneration becomes impossible on poor soils, and more difficult on good ones, where the vegetation is stunted as well as where the disappearance of the soil-covering has led to the dessication and hardening of the surface layers.

It is impossible to lay down a hard-and-fast rule on this point; each case presents its own peculiar features. However, many fires cause damage equivalent to a loss greater than a single year's increment and may amount to that of four years, corresponding approximately to the period necessary for the reconstruction of a protective screen. Appendix F furnishes an example of the estimation of an injury of this nature.

In some cases, the retardation consequent on the loss of the undergrowth may entail an inferior development of the growing-stock, that is to say, not only a ***shortage of volume*** but also a ***falling off in quality and size.*** In this case the estimation would be analogous to that in Section 81 or Appendix D, article 2: ***Depreciation.***

Another side of the question demands notice. The fire, by reason of impairing the vitality of the trees, increases the danger from and the severity of cryptogamic diseases. In addition, phytophagous insects multiply rapidly in an unhealthy forest.

These last two considerations are, it is true, merely threats of possible future danger, but they may occasionally prove most devastating calamities and bring about the total ruin of the growing-stock. An illustration may be borrowed from Dr. Altum. A compartment in the Eberswalde pine forest was partially run through by fire, the bark of the trees affected not being visibly injured. At first it appeared as if the fire had merely scorched the needles which eventually withered. All these trees, however, were subsequently invaded and rapidly killed by *Pissodes notatus*, but for which they assuredly would have recovered. On the other hand, these weevils did not attack trees which had not come under the influence to the fire.

In agreement with eminent mycologists and entomologists, M. L. Fabre ascribes to exhaustion the etiology of obscure diseases which remain unfathomed: " Weakened, sapless and exhausted, the trees are debilitated and starved of nitrogen. This is the opportunity of those infinitely minute beings which lie in wait for an easy prey—an enfeebled organisation."

117. Earthworms.—The fire destroys not only the soil-covering of dead leaves and the contained bacteria, but also all living things sheltered by it, and amongst these earthworms merit special mention. It has been shown that they are the great factors in the reduction of vegetable matter into soil. Darwin, von Hensen and Dr. P. E. Müller have all demonstrated that their work results in perfect natural cultivation of the soil, the fertility and productive action of which they enormously increase. Von Hensen for agricultural land and Dr. Müller in the forest, have proved that earthworms are partly instrumental in the formation of mould, that is to say, the amalgamation of organic matter and mineral constituents. Despite the absence of cultivation in forests the soil is loosened and improved, thanks to the numerous animals which swarm in the carpet of detritus, excavating beneath it galleries which enable air, gas and water to penetrate to the sub-soil.

Wollny's observations have established the rapidity with which organic débris decompose after their passage through the intestines of earthworms. M. Henry found, in certain forests, that in one year one-fifth to one-fourth of the annual fall of leaf was transformed into humus by the action of these invertebrates. In the opinion of Professor Flahault, "a sound treatment will preserve to the forest all its workers, earthworms and larvæ of all kinds."

No better summing up of the whole question is possible than the following *résumé* of these discoveries, drawn up by M. Henry preparatory to complementing them by his own researches: "The abundance of nutritive and assimilable constituents of the soil are increased by the agency of earthworms. Their most important service consists in rendering the sub-soil porous and permeable, and in reducing it to that granular condition which enables roots to penetrate readily and gives free circulation to the air essential to them."

Wyssolzky and von Hensen maintain that in the absence of worm-burrows the root systems could not penetrate so deeply in compact soils, nor, consequently, could they profit by the humidity due to sub-soil water. Dr. Müller explains the progress of the roots in the soil by the assistance rendered by earthworms in turning it over and fertilising it, so that banks of clay, unfit for the growth of most plants, are transformed into sites favourable especially to plants with rhizomes. It is an agency of infinite power and perfection. Wollny found the improvement caused by earthworms to amount to 27·5 per cent.; permeability and capilarity had, therefore, been enormously augmented. Finally, Millsom's experiments in Guinea brought to light that these animals throw up 25 kgs. of worm casts per square metre in one season.

M. Henry assures us that the removal of the cover of dead leaves and débris, the layer in which the earthworms find their nourishment, results in their emigration; their absence for several months is sufficient to entail an extraordinary hardening of the surface soil, or, in short, its deterioration from a vegetative point of view. Now, a fire affects this cover far more profoundly than a mere raking off, and should it reach a certain degree of intensity, it drives away for a long period these creatures whose provender has been entirely destroyed.

With the intention of describing typical sterility, M. Mathey wrote: "The soil is astonishingly poor in earthworms. Its return to active fertility is distinguished by the appearance of a vegetal carpet and the correlated reappearance of worms. * * * Their colonies work up and loosen the soil." The reverse phenomenon of a decrease in the animate population is the first indication of decadence in forest degenerating to denuded land.

The adoption of Ebermayer's classification, or that of Dr. Müller, for deposits of humus, is merely a matter of terms or groups. Let us give to the products of what Hilgard

calls *eremacausis*, the generic name of *mould;* it is *mild humus* (the *mull* of P. E. Müller), and is the commonest of the humus compounds met with on agricultural or garden soils. We will apply the designation *peat* not only to the accumulation of plants in submerged localities, but also to the tenacious surface layer found in dry sites, such as the *carbuncular* of the Germans, the *torf* of Müller and the *raw humus* of Wollny.

All botanists agree in recognising the great difference in fertility between sweet soils, well aërated and loosened by earthworms, and carbonaceous humus or sterile peat devoid of a fauna and consequently of a flora. M. Van Schermbeck observed of one place that "earthworms, those untiring labourers, have departed. * * * The consequences soon become manifest: in place of a healthy surface soil one very soon finds an acid humus, to be succeeded ere long by a kind of peat."

M. Henry and Wollny recognise the possibility of the appearance of raw humus when moisture diminishes or fails, as may follow after exaggerated thinnings. Drought is one of the agencies which co-operate in the transformation of mould into peat, whether it be due to slow-acting causes such as heavy fellings, the removal of shrubby growth giving access to desiccating winds, or browsing, or else to abrupt ones such as fire. Drying and hardening, the results of external meteorological or internal zoological agency, are reciprocal phenomena, leading to one another, and are invariably translated by a perceptible decrease of vegetation and even at times by complete decay.

The damage occasioned as discussed above cannot, in the present state of sylviculture, be calculated with precision. However, controversy can be avoided by accepting the minimum loss, shown by Professor Schwappach to amount to 3 per cent. of the total increment of the growing-stock, taking into account both the decrease in volume and the deficit in value per unit of inferior marketable products. This damage, however, is felt only at the time of sale, and, therefore, must be discounted for the period elapsing between the date of the fire and that of the final felling.

Indirect injury.

118. Increment of individual trees persisting after fire in high-forest.—In a high-forest crop, do the

individual trees which have escaped the fire benefit by the extra amount of food and air available owing to the death and removal of their competitors? If so, is the resulting increment sufficient to warrant its being taken into account? Or are the new conditions, on the contrary, unfavourable? This problem is similar to that considered in Section 84, but the solution here is complicated by the introduction of a vague factor: the degree of density, or rather of incompleteness due to the disappearance of the burnt trees, at a time and under circumstances which are inopportune from a cultural point of view.

In causing the removal of a portion of the growing-stock an accident certainly leaves a supplementary store of nutritive materials in the soil available for the trees that are left; but, as observed by M. Mer: "In order to profit by this abundance, they must possess a corresponding excess of starch furnished by their leaves. For this it is necessary that the crowns should find themselves in better conditions of light and air." But whoever has practically attempted these delicate thinnings will agree that if fire is successful in setting up such conditions it must be by pure chance and but extremely rarely. It must be admitted that during the first few years following the competition between transpiration by the foliage and suction by the roots is diminished—but to what extent? This cannot be stated precisely in the absence of a sufficient number of measurements and experiments, and no general figures applicable to different species, growing under varying conditions of soil and aspect, can be quoted with any probability of exactitude.

M. Mer has closely studied the effect of opening out in high-forest in France, observing the detailed precautions of the German school. The results obtained by him appear to be decisive, but they apply solely to thinnings in spruce woods. This, however, is not the case we are concerned with, for a fire is not a thinning or, rather, is more than a thinning. In pine woods its effect is usually excessive; the growing-stock is destroyed. In forests of silver fir, which cannot burn as a whole, a proportion of the trees will be killed, but this will not place the growing-stock in the condition obtaining after a regular felling. Among species prodigal in dormant buds, notably the oak, its influence is harmful. The increased growth of the trees left is due to the greater access of light and to the excess of nourishment available; both of which causes tend to the development of epicormic

branches so fatal to the symmetry, value and future of the tree.

The fire, whether intense or light, brisk or slow, raises the temperature of the cambium to a greater or lesser extent. It is well known that the heat of the sun often dries up healthy trees, raising the bark accustomed though it is to direct solar rays; how can one then repudiate the much more abrupt and violent effect of flames, even though it is not at once patent to our very limited means of investigation.

It is probable that the sum of the accessory effects of fire not included in the calculation are negative, in other words, that the final adjustment leaves a deficit. We are therefore of opinion that this suppository abnormal increment should not be taken into account.

The whole of the above argument applies to old trees with a thickened rhytidome; where the growing-stock consists of hornbeam or beech, in which species the thin bark affords but little protection to the cambium, one can affirm that even a light fire is distinctly harmful to the survivors.

In young woods, insufficiently protected by an inadequate bark, or attacked at an unfavourable season, even an apparently insignificant fire inflicts distinct injury. In such case a superficial inspection by an inexperienced person may lead to serious loss, should the owner decide against cutting back, under the impression that the reduction to ashes of the grass, dead leaves, débris and inferior shrubs is more or less advantageous. Such a delusion would be rapidly dispelled by a reference to M. Borel's measurements recorded in Section 24. In one of the cases cited by him, the failure to cut back in a 23-year old coppice traversed by an apparently insignificant fire, resulted in the following actual loss.

At the time of the fire the coupe would have readily realised 340 francs, and the sale would have saved all felling charges. At the normal age of exploitation, 33 years, the coupe only realised the above figure instead of its normal value, 620 francs. The prevailing rate of interest is $3\frac{1}{2}$ per cent.

1. The sum of 340 francs at compound interest from 23 to 33 years at $3\frac{1}{2}$ per cent. would have become :—

(i)

$$340 \times 1{\cdot}411 = 479{\cdot}70 \text{ francs.}$$

or an increase of :—

479·7—340	=139·70 francs.
Carried over ...	139·70

Brought forward ... 139·70

2. At 10 years of age the regrowth would have been worth to an owner unwilling to sell the property :—

$$\overset{\text{(iii)}}{620 \times 0{\cdot}473} \times \overset{\text{(i)}}{(1{\cdot}411-1)} = \quad . \quad . \quad . \quad . \quad 120{\cdot}50$$

Total loss . francs. 260·20

This loss is far from negligible. In addition, the danger of the death of the root-stocks and the consequent ruin of the forest was incurred.

119. Minor produce: Resin—Cork—Dogwood—Truffles.—Resin, though an accessory product, is inseparable from the dominant crop.

It is the same with cork, exploitation of dogwood, of buds and needles of certain species of pine, which are manufactured into vegetable bristles, or from which a balsamic oil is extracted. The method of their valuation is the same as that of minor produce in general.

If they are exploited periodically, their values are added to those of the fellings or appear as intermediate revenue, according to the date on which they fall due. Should they be annual and regular, the corresponding capital is obtained by multiplying them by the first line of table III. For instance, the collection of resin leased for an annual rent of 20 francs, at a rate of 5 per cent., represents a capital of $20 \times 20 = 400$ francs.

When this continuity is limited to fixed periods, with unproductive intervals, a condition is set up similar to that of a forest regenerated at the same date throughout its extent, and where it is not intended to continue the prescriptions in the next rotation. Thus the collection of resin may bring in 25 francs per annum for a period of 30 years; after which it ceases; the value of the sum of the yearly yields at the end of the rotation at the rate of 5 per cent., amounts to $25 \times 15{\cdot}372$. At any given moment it is represented by the formula $C = \frac{1}{t}\left(1 - \frac{1}{(1+t)^m}\right)$; m indicates the number of years over which the lease extends.

Finally, it may be necessary to value a yield suppressed for the time being but reverting to its regular annual course after a certain interval. Such a situation would arise after the destruction of a selection forest. The formula $C = \frac{1}{t(1+t)^m - 1}$, gives the factors by which the annual and

continuous revenue, which will first fall due after the expiry of m years, must be multiplied in order to ascertain the amount of the corresponding capital. For example, the capital corresponding to the lease of the collection of resin at an annual rental of 15 francs beginning 10 years hence is $15 \times 2{\cdot}983$.

Truffles.—Should the forest produce truffles this item will also have to be considered. When the fire completely destroys the trees, including their root-systems, or the lower storey, at the time of the regrowth of the truffles, their food materials are cut off, since the mycelia develop at a comparatively deep level at the expense of deep rooted plants, so that grass or shallow rooted vegetation, which springs up abundantly after a fire, would be of little service to absolutely hypogeous mycelia.

On the other hand, should the fire take place at the time the truffles appear, the development of the semi-epigeous mycelia, dependant on shallow-rooted herbs, may not only be hindered but actually killed outright by the heat and as a result of the destruction of the soil-covering.

For an accurate estimate of the damage under this head the valuation should be postponed till the following season.

120. Meteorological Accidents.—In certain circumstances one may ascribe to the fire several other kinds of injury, not only to the area burnt over, but to adjoining unburnt growing-stocks and to neighbouring agrarian holdings. The present section refers particularly to the last mentioned and is principally concerned with cultivation belonging to the proprietor of the burnt forest.

Humidity.

In a dry climate any diminution in the rainfall leads to deficiency or even failure of the harvest. Now, assemblages of trees increase the degree of humidity of the atmosphere, and the destruction of a proportion of them may result in the death of the rest. Reafforestation is frequently possible only in the proximity of existing woods. M. Henry has collated the numerous experiments made in this direction, in different countries, at all altitudes, under the most varying conditions and with diverse species. They have furnished proof of the increase of atmospheric precipitation induced by masses of trees, thanks to their abundant transpiration, to their marked prominence facilitating the condensation of clouds,

to water vapour arrested in the tree tops, etc. "This influence is beyond doubt. * * * *Forest-sheltered zones are moister and yield more abundant harvests.*"

A mere fringe of tree growth is sufficient to ensure the adjacent fields being fresher, more vital and less exposed to drought. More especially in mountainous country is there a striking connection between the extent of land under forest and the state of the subjoined cultivation; below large and healthy woods rich fields are encountered.

The forest maintains in its surroundings that degree of humidity so essential to the active production of all the phenomena of vegetal life; its influence extends beyond its boundaries. The excess water flowing from woods fulfils a most important rôle in agriculture. Disafforestation reduces the relative humidity during the hotter months.

The physical attributes of the soil may double or treble the aridity entailed by the clearing of forests. Denuded soil on a warm aspect is frequently totally incapable of cooling the air down to saturation point.

M. Van Schermbeck, taking molecular cohesion into consideration, states that a layer of heated dust absolutely prohibits an otherwise permeable soil from absorbing rain water. This is corroborated by agriculturists who have often been in a position to verify the fact. The degree of hygroscopicity of the soil regulates the volume of liquid which it is capable of imbibing. But little permeates into a dry medium; to obtain the full benefit from aërial humidity, the superficial layers of the soil must always be moist, and to this end must be furnished with a covering of vegetation. The quantity of organic nitrogen contained in it plays an important part.

So far back as 1866, the forest school at Nancy had discerned another factor in the exaggeration of this dryness. Evaporation takes place with far greater rapidity in the open than under cover of the canopy of a forest; the difference is as much as double in the winter and four times in the summer.

These causes combined are responsible for remarkable results in particular localities, such as South California and Arizona. Here, on the authority of M. Ducamp, as a result of fire, the country remains denuded and incapable, for a long period, of producing anything but a sparse and poor vegetation. In some of the territories thus ravaged by fire, so hard a crust forms on the surface that up to 90 per cent. of the atmospheric water fails to penetrate into the

soil. Thus vast volumes of water are diverted from their proper channels of circulation.

A suitable cloak of vegetation would have caused part of it to be returned to the atmosphere and the rest, stored in reserve, would have gravitated slowly towards valley bottoms, springs and canals.

Commenting on the records of German forest stations, M. Grandeau concludes: "Forests increase the mean annual relative atmospheric humidity. In well-wooded regions, the condensation of atmospheric moisture into clouds is more continuous than in denuded ones. In the first, at all seasons the air is more charged with vapour, particularly so in the summer when the proportion is nearly double.

Clearing of forests over large areas perceptibly reduces the relative humidity, more especially in the hotter months, and in hot climates, consequently, the duration of rainfall and its intensity are decreased." "Forests attract rain, which falls more frequently and in greater abundance in wooded districts than in those in which forests are scarce. The excess of atmospheric precipitation may amount to 20 per cent." (*M. Henry.*)

In his "Cosmos" Von Humbolt writes: "By clearing mountains of their trees, man prepares a water famine for the generations of the future." The fact, popularly expressed in the words "forests make rain" ("*la forêt fait pleuvoir*"), and first well established by the Nancy Forest School, is irrefutably corroborated by the most recent researches of the Russian Forest Service, as well as by all the recorded observations in Germany, Austria, Switzerland and even India. Finally, Dr. Nisbet sums up the conclusions of meteorologists by averring that *rain is more abundant in the neighbourhood of forests.*

Water retained by the crowns of the trees, amounting in forests of resinous species to half the volume of the total fall, evaporates and goes to increase the quantity and duration of subsequent rain, whether over the forest itself or in the vicinity. "The same may be said with respect to the water absorbed by the roots and transpired by the leaves. This restitution of vapour replaced in circulation is obviously beneficial; it tends to prevent the drying of crops and favours the formation of dew. A forest is indeed a great reservoir of moisture." (*Guinier*). It is also a regulator; the evaporation in the tree tops absorbs considerable heat, consequently, the air above woods is much cooler than

elsewhere. The forest therefore fulfils the rôle of a condenser.

The considerable evaporation emanating from the forest is at its greatest during the season of active vegetation, since at that time the moisture from the clouds arrested in the crowns is added to that transpired by the leaves; in consequence, it is more especially during the hot, that is to say the dry season, that it manifests its influence, and it is precisely at that time that it is most useful. This theoretical conclusion is confirmed by meteorological observations, and rain gauge readings in forest tracts show from May to October a rainfall 24 per cent. in excess of that in bare land, whereas, during the remaining six months, the difference does not exceed 12 per cent. Not only, therefore, do forests *cause rain*, but, further, they regulate to a certain extent its periodicity.

The knowledge of these facts is being gradually disseminated among laymen. The great losses sustained in the United States of America owing to continued drought, have greatly influenced public opinion in favour of the establishment of State forests and their preservation. The growing popular conception is reflected in specialised periodical publications which lays stress on the subject in numerous articles "*in the interest of agriculture intimately associated with the conservation of forest tracts, on which depends the prosperity of the harvests.*"

Hail.

M. Puenzieux, head of the Forest Service of the Swiss canton of Vaud, has recently drawn attention to the protective influence of forests by tempering storms, attracting lightning and restricting the frequency of falls of hail. The latter, as observed by M. Mathey, "replace gentle rain in pastures denuded of forests, cut up, lay waste, excavate, and further instantaneously chill the atmosphere." The same author mentions several valleys which are subject to constant devastation since their disafforestation.

In the whole of German Switzerland, great reliance is placed on belts of resinous trees at intervals; these act as hail-breaks to fields.

In several cantons of the same country, it has been observed that frequent hailstorms followed on the felling of certain forests and ceased when they had regrown.

Owing to the same cause, hundreds of communes in France are devastated periodically. Since the disappearance of its protective forest of thirty years ago, the Bresse of Louhan experiences considerable losses on account of hail.

Bequerel, as the result of 18 years of study of the progress of storms, concluded that *forests successfully shelter cultivation situated near their boundaries.* In this he is supported by numerous other competent observers.

In the vicinity of Lyons, M. Servier's plantations, though of very limited extent, have resulted in transforming hail to rain. In the Swiss canton of Schaffhousen, the forests on hill tops are preserved by law, in view of their protective influence against hail.

It is probable that the phenomena indicated above only occur where considerable tracts are denuded of forest growth; less, however, than 50 hectares, for observations extending over 20 years in a corner of the Bresse district, have shown that a wood of that area has served to allay or to divert hailstorms. However, we are compelled to admit that any estimate of injury based on these considerations would prove a matter of great difficulty, seeing that data and experiments as to the exact influence on vegetation so far are entirely wanting.

It would be an easier matter to find more precise foundation for a calculation of damages in other influences of afforested areas, such as the following.

Frosts.

The humidity disseminated around a forest reduces nocturnal radiation in a marked degree, and consequently, the white frosts of spring and autumn, so common in dry climates.

M. Puenzieux ascribes the recrudescence of fogs and frosts to the clearing of forest lands.

The shelter afforded by tree growth reacts favourably against spring or early frosts, and the forest regulates the temperature. The distance to which this protection extends depends mainly on the relation between the prevailing critical periods and the latitude.

M. Borel has been able to calculate the distance to which the sheltering influence of a wood makes itself felt, which regulates the interval to be maintained between protective belts in a given locality.

Professor Ebermayer lays stress on the important part played by the canopy in the protection of the soil against nocturnal radiation. Thanks to it the extremes of temperature of the soil and air are lessened and autumnal or late frosts become rarer. The dead soil-covering prevents cold from penetrating to the sub-soil.

Wind.

But for the protection afforded by trees, plants would be prostrated by the violence of the winds. The smallest spinney protects the adjacent fields from scorching blasts which wither and even kill the grass.

M. Puenzieux and M. Borel have proved the fatal effects of wind on agricultural crops, particularly in orchards, and urge the efficacy of arborescent screens.

In Russia, devastating winds from the Steppes blight the wheat, and forests alone afford adequate protection.

In this case the tree growth need not extend over a large area in order to exert a perceptible influence. The quadrilateral plots of oak on the plateau of Lannemezan or at Plougastel, the simple cypress hedge of Provence, the lines of spruce at Orquevaux * * * * all afford effective protection; neither gardener nor farmer could dispense with them. So adequate are trees thus disposed that, as stated by Wyssotzky, the Russians preserve wooded belts throughout their black-soil lands—the prodigiously fertile *tchernozem*. These groves shelter cultivation from desiccating winds, decrease evaporation and preserve the snow. Whereas in June the grass of the open Steppes is already withering, that in the rectangles enclosed within the planted screens remains still green and sweet, and yields a revenue half again as great.

Where the protective belt is destroyed, it is easy to calculate the indemnity according to the deficient crop or total failure of the harvest following on the suppression of the forest shelter, as compared with the yield of former years.

Springs.

No one now-a-days contests the instrumentality of forests in the preservation and regulation of springs. The dictum of scientists throughout Europe, in the United States and in

India*, the contributions to hydrological publications in all countries, amply demonstrate the beneficial influence of forests on the constancy, the volume and the regularity of springs. With the removal of forests which clothed their catchment areas, springs disappear, or at least, greatly decline and become irregular, but reappear or increase on replanting. Every day brings forth new and more convincing facts of the same nature as the precision and competence of observers increase.

An apparently insignificant spinney is often of the greatest value, and in certain regions they play so considerable a part that their existence becomes a matter of the highest importance. M. Ducamp gives prominence to the following asseveration printed in an American journal :—

"In Southern California the dependence of agriculture on water flowing down from the hills is strikingly disclosed. After a destructive fire in a forest district, the harvest is in deficit throughout the zone fed by the catchment area burnt over. This reflex action is not alone immediate and obvious, but the results of the injury persist for a long time, in fact until the vegetation in the region has regrown sufficiently to arrest surface flow. Mr. Touney, the special forest agent for the Arizona division, places so much importance on the gain of a few years in the reconstitution of the tree-growth that he urges not only the rigid protection of the burnt areas, but further, radical measures of replanting, untrammelled by false economy, to enable reafforestation to be effected with the least possible delay."

Some twenty years ago a town of the Central Plateau, almost suddenly, was deprived of water, or, at least, found its water-supply seriously diminished, after a fire which destroyed a forest above and around the source of its springs. These resumed their normal flow after re-stocking by planting had been achieved.

Here there can be no general rule. Each case is invested with its own peculiar consequences, and claims to compensation must be examined on their own inherent merits.

Floods.

The beneficial action of forests in restraining freshets, preserving the soil from erosion and arresting surface flow

* As regards India, the writings of Sir W. Schlich and Dr. Nisbet may be consulted, and more especially Mr. B. Ribbentrop's "Forestry in British India" and Mr. Eardley-Wilmot's "The influence of forests on the storage of the water-supply."

up to half of the total rainfall, will be nowhere denied. It is also universally conceded that *tree-growth affords the surest prevention of inundations.*

Since Lomet in 1794, the authors who have dealt with this question are too many to enumerate here, and to comment on their observations would be superfluous in face of the general acquiescence regarding the facts.

Engineers, foresters, geologists, publicists, French and others, are all unanimous in testifying to the powerful action of "the forest, the sovereign regulator of the earth's water system."

In case of flood claims to indemnity are supported by the law of the 8th April 1898. The text, in connection with Articles 1383 and 1384 of the Civil Code, allows the owner of the lower estate to claim compensation of injury from the owner of the estate immediately above it if the removal of trees which protected the soil from denudation and excavation results in débris, mud, gravel * * * * being washed down, disorganising the normal flow of water *(apport de matière, boue, graviers * * * * aggravant la servitude naturelle d'écoulement)*. Such conditions are frequently met with in mountainous tracts. In 1898, excessive fellings amounting to clearing were carried out on the slopes forming the catchment area of the Adour, at a point where till then erosion had been unknown. The first rain in the valley of the Lesponne brought down an exceptional rush of water which, instead of being absorbed and retarded by the foliage and the soil-covering as hitherto, now carried all before it, soil and dwellings.

Pending the precedent of an action at law, this doctrine has yet to receive the sanction of an actual decision in a court of law.

As in the next case, each accident must be the subject of a special arbitration and investigation, which estimates the loss suffered.

Avalanches.

The same consensus of opinion ascribes to forests great potentiality against avalanches. Artificial bulwarks, built up at threatened points, are mainly preparatory to re-afforestation ; forests constitute the only permanent screen capable of withstanding the violence of natural phenomena.

121. Estimation of indemnities which have not been the subject of a special calculation.—In the

course of this work, whenever the nature of the injury considered did not permit of absolute precision in the estimation, we have adopted the minimum; but often the party injured could rightly claim the mean.

There remain a number of injurious effects of fire which it is almost impossible to value separately because they escape our observation, are little understood, difficult to estimate, or only become perceptible after the lapse of time. Nevertheless, in the aggregate, the owner suffers appreciable loss through them. We have readily omitted all those for which the existing scientific data or the insufficiency of our methods of investigation do not permit us to fix exact values. Meteorological accidents will nearly always be included in this class. It happens, too, that certain detrimental consequences which could ordinarily be estimated do not, at the time, appear sufficiently serious to justify an indemnity and are consequently neglected. When, after the lapse of several years, the injury becomes apparent it is too late to establish a claim. In this way, damage arising from certain causes is rarely incorporated in the calculations, though they are practically inseparable from a fire. Such causes are: disorganisation or impairment of the vitality of the cambium, temporary suspense or slackening of the flow of sap, disease of the rootstocks, debility of young standards, unpropitious season for the production of coppice on cutting back, invasion of useless shrubs, contingent failures in replanting, combustion of dead leaves and grass, destruction of the shrubby undergrowth, disappearance of humus-forming bacteria and of earthworms, etc. In short, whenever arbitration is in doubt, is inexperienced or is guilty of omission, it is probable that the owner of the forest burnt will suffer. Even should he receive ideal justice and the damages awarded attain to the full value of the injury, he is still faced with the problem of the best use to be made of the indemnity. His forest offered a stable investment, a safer revenue than that of most immoveable properties, and it is not often possible at short notice to reinvest the sum recouped at compound interest under conditions of sufficient security.

Finally, considerations of sentiment must be taken into account: inclination, personal convenience, sacrifice of the picturesque, the correct appraisement of which is most difficult.

These questions—some material, others of sentiment—cannot equitably be overlooked. Moreover, the courts assent to these claims on the same basis as those relating to expenditure on extinguishing fires, modifications of plans and locations, out-of-pocket expenses in connection with perquisitions, removals, conferences, sales, consultations of experts, delays in maturity of credits, forfeitures for failure to carry out contracts, or for failure to deliver goods to contract. The code authorises damages being awarded according to circumstances.

It is not possible here to fix a definite general figure, for each case entails varying unforeseen expenses, but it does not seem probable that the amount could fall below 10 francs. It is often ten times that sum, and in certain circumstances has reached one thousand francs. When the estimate cannot be based upon special calculations, it must be framed in the form of a supplementary percentage or a lump sum in excess, based on careful and moderate appraisement.

The party injured should place before the magistrate or selected arbitrator an account of these accessory items for redress, and it is the duty of the judge in the litigation to verify them.

122. Climatic and economical consequences.—The phenomena reviewed above are amongst the chief elements of climate. Seeing their relation to forests, we may, therefore, apprehend some effect of the latter on climate, and this has indeed been proved by the researches of several scientists.

Following on the clearing of forests the local climate deteriorates and meteorological conditions are profoundly disorganised. The prosperity of agriculture, the public welfare, are dependent on "the preservation of the normal proportion of land under tree growth, the great law of equilibrium, the vital circulus." Professor Flahault expresses the same opinion: "the denuded zone in the mountains must be reclothed. To reconstitute those forests is to restore that order in nature without which all agricultural economy is shaken to its foundations." M. C. Claudot was led to an identical conclusion by his geological and meteorological studies: "The services rendered to agriculture by neighbouring forests are multifarious; they protect it from all atmospheric calamities."

The report placed before the Belgian Government in 1901, in support of a plea for a budget grant, urged the

following considerations: "The woods purchased by the State afford to adjoining fields invaluable shelter against climatic inclemencies. Their incorporation in the national domain is justified on all counts, and notably on the score of hygiene." In France, those charged with the care of agricultural improvement, guided by the same principles of general utility, advocate, and at the present moment subsidise, important plantations on the Lannemezan plateau.

The Agricultural Society of Marseilles complained of a deterioration of the climate following on the abuse of privileges in the forests after 1789. The famine of 1892 in Russia was ascribed to the same cause by Professor Geffeken, Major Law, the *Edinburgh Review* and the *Times*. Disastrous climatic changes have attended the disappearance of forests in Syria, Asia Minor, Greece, Russia and many regions of India.* Central Asia, once a garden of exceptional fertility, is now a desert. The evil is the natural corollary of the disappearance of trees, the sole remedy is their reintroduction. Even in France the situation induces M. Guénot to raise the alarm: "The Pyrennees are being denuded; in a century the clearings will have led to depopulation and solitude."

After a careful analysis of the causes leading to the general drying up of countries, Professor Dumas is forced to the conclusion that it is due to the destruction of the vegetal covering and to the ignorance of the part played by forests.

Usually, greater importance is attached to the more violent phenomena; it is not these, however, that are most influential from the point of view of inhabitability. Hygiene is of universal human interest and should be the foremost consideration, and, under most circumstances, is intimately connected with forests.

That clearing of forests on too large a scale caused detrimental modifications in the physical conditions of a country and endangered the welfare of its inhabitants was well known to the Romans. Paludal diseases follow after clearings, especially in tropical regions. On the other hand, in feverish countries such as the Roman Campagna, the Russian Steppes, the Maremma of Tuscany, the Landes and others less known, reafforestation, by drying the swamps and morasses, has diminished unhealthiness. Everywhere the miasmas of marshy zones have given way before advancing plantations, to reappear on the removal of the protecting

* In this connection see M. Ribbentrop's "Forestry in British India," pp. 39 to 59.

forests. The alternations of salubrity and malarial conditions, of great prosperity and deepest misery, which have emphasised the existence and subsequent disappearance of tree growth, are contemporaneous facts. In Belgium, M. Crahay "justifies the solemnity of an official festival in honour of sylviculture by its important social influence. *A most salutary effect is exercised by forests on climate and public hygiene.*"

The area under vegetation need not necessarily be extensive in order to exhibit its corrective power. A single Eucalyptus can drain the excess water from 20 acres. In Algeria an arborescent hedge of but a few yards in height secures a whole household from the pathogenic germs of marshy soils. In a few years limited plantations have enabled a thin and debilitated population to regain strength and to multiply. "The introduction of trees affords the best method of drying and improving the salubrity of boggy localities, the haunts of malaria. A thousand instances prove it." (*Henry.*)

According to Endres and Fernow, woods offer an obstacle to the spread of certain epidemic diseases, such as cholera and yellow fever.

The question has, however, a still wider outlook. The struggle for water in Western America is traced by M. Ducamp to its true origin: the want of forest conservation. In these vast States the welfare of millions of individuals depends upon the precious storage of the large water-basins. The political, social and economical problems, even the life of the nation, are correlated with, or subordinated to the regulation of, the water-supply of the country. Now, irrigation is indissolubly bound up with the existence of forests on the mountains, where the chief watercourses originate. It is the aim of the *American Forestry Association* to endeavour, by every possible means, to teach the public that the words: *irrigation—forests,* stand for one and the same thing. Enlightened by a true perspective, the United States Congress decreed, in 1902, the constitution of fresh *National Reserves* in their forests. This is most eloquent pleading in support of our thesis, prompted by the need of stores of timber, of protection of soils, permanent regulation of rivers, and in the interest of agricultural, industrial and commercial undertakings.

Once, Tripoli was clothed with abundant vegetation which secured the stability of the sand, making it possible to

establish superb cities surrounded by prosperous cultivation. It formed then one of the granaries of the Roman Empire; now we find but the desert and ruins. The whole of this plain has become sterile owing to the disappearance of the woods of the interior, which sifted the water and compelled it to flow gradually to the large permanent rivers. M. Ducamp reports that now but a few fields of barley and alfa are to be found, affording a meagre maintenance to miserable and decimated tribes.

Such is the result of a senseless devastation which unfortunately has swept over the whole of North Africa like a pestilence.

In a work no less admirable for the uncontrovertible logic of his deductions as for the trustworthiness of his facts, M. Boucard has portrayed a region of France. This picture of local vicissitudes would practically fit those of most countries that have experienced similar times of stress. The details may vary, but the cause and effect remain the same as a whole. Sologne remained prolific and populous as long as the major portion of its territory was covered with woods. When these disappeared, ravaged by defective exploitation, overgrazing and constant fires, with them she saw her abundance and health fade away. Insalubrity and misfortune was the natural corollary of the clearing of forests. Five hundred thousand hectares doomed to barrenness became a centre of pestilential infection. A heart-rending spectacle of misery and tribulation was presented in a population discouraged by its impotence, overcome by disease and decimated by premature deaths * * * * * * In thirty years the sowing and planting of pine trees in all quarters has restored this unfortunate region to prosperity, health and productiveness and to the vitality of ease and well-being.

In such cases there is no need for figures. At what sum can one rate the human lives that would fall victims to a return of the morbid miasmas and intolerable privations now hopefully removed for ever by the forests. A quotation from A. Theuriet will form a fitting conclusion: "In its forests lies the heart of a nation, and a people without forests is very close to extinction."

PART IV.

SPECIMEN REPORTS—TABLES.

Appendix A.

MEMORANDUM OF THE PRINCIPAL OPERATIONS TO BE CARRIED OUT ON THE RECEIPT OF INTIMATION THAT A FIRE HAS OCCURRED.*

1.—In the Field.

Before setting out for the site of the fire, the Conservator and the Deputy Conservator must be informed. If the fire is a serious one telegraph to the Director of Woods and Forests, as well as to the Prefect and Sub-prefect.

Concentrate assistance.

Take steps to put out the fire.

Ascertain the area burnt over, either by stepping out the distances or by exact measurement. Distinguish between those portions where the growing-stock itself is burnt and those where the undergrowth alone is destroyed.

Record the locality, roads, paths, slope, direction of the wind, etc.

Enumerate the rootstocks killed or damaged (intensity of damage).

Natural regeneration. Cost and extent of artificial plantation. Selection of species. Proportion of blanks normally replanted.

High-forest.—Enumeration, calculation of volume and estimation of value of trees killed and of trees seriously or slightly injured. Opinion as to their future prospects. Proportion and distribution. Annual increment.

Proportion of failures—Canopy.

Comparison with the normal type.

Investigation on the debility of the future standards and on the loss of height-growth.

Exploitable material.

Coppice.—Condition and density of the crop. Proportion of the species.

Necessity or futility of cutting back. Cost and time of cutting back.

Valuation of the coppice burnt. Actual value. Yield at the normal age of exploitability and at the premature age of failing imposed by the

* This memorandum is for the guidance of Rangers in France.

necessity of concordance with the rest of the coupe. Yield of the same coppice freed of the cover of certain classes of standards.

Investigation of useless shrubs.

General and economic conditions of the exploitation.—Valuation of the soil.

Local market rates of timber. Transport. Markets.

Annual recurring charges.

Dead leaves.

Grass. Heather. Moss.

Minor produce.

Meteorological phenomena. Springs. Inundations.

Economic consequences.

Personal convenience of the proprietor. Objects of management and utilisation of the forest. Current contracts impeded.

Expenditure on extinguishing.

In office.

Report to the court.

Précis of the working plan and prescriptions.

Statement of coupes already worked in the area burnt over.

Rate of interest.

Comparison of results obtained by anticipating or postponing the next felling. Decision thereon.

Calculation of the indemnity.

Joint report drawn up in collaboration with the railway representative if the fire was caused by a locomotive.

Administrative report or statement of valuation.

Appendix B.

REPORT ON A FIRE BURNING ONLY DEAD LEAVES.

Dated the

We, the undersigned , depose :

On this date, at about two P.M., a fire broke out in the communal forest of Brottes, in sub-coupe 2. The cause is unknown and difficult of determination as it originated in the heart of a dense thicket overrun with thorns, some distance from any road, and at 35 metres from the nearest point on the outer boundary.

The fire was extinguished by M. F. M. .... of Brottes, after it had extended over ten *ares* of 11-year old simple-coppice of oak and hornbeam, doing no damage to woody growth. The dead leaves were only partially burnt, and the moss remains nearly intact.

The only damage effected is the loss of half of the dead leaves. Their total dry weight may be accepted as 3,000 kgs. per hectare. According to Mr. Henry's observations, they would have fixed 55·5 kgs. of nitrogen during the next 18 months, *i.e.*, before their complete decomposition. To make good this injury, fertilisers containing the same quantity of this element must be brought on to the area. The soil is light and stony so that only organic manure is suitable. In such the cost of nitrogen amounts to 1·80 francs per kg.

Consequently, the damage is calculated as follows :—

$0{\cdot}10 \times \frac{55{\cdot}5}{2} \times 1{\cdot}80$ francs	= 5 francs.
Transport and spreading of manure on contract . . .	1 franc.
TOTAL .	6 francs.

The total indemnity for damage caused to sub-coupe 2 of the Brottes forest by the fire of ....19......is determined at six francs.

Appendix C.

Report on the Destruction of a few Stools and Standards by Fire.

Dated the

We, the undersigned , depose :

On the 19th instant, a fire broke out in coupe 22 of the communal forest of Neuilly, now under working, which is subject to rights to fuel. The contractor is M. A. B. ...... of Brottes. The fire arose through the negligence of M. N. A. ...... of Brottes, who, while smoking, threw down a lighted match. The fire was partly put out by A ......, its unintentional author, who sustained severe burns while doing so.

The fire spread over two *ares* and consumed the grass and dead leaves here and there ; it scorched an oak of 25 c.m. in girth and 3 oak stools sufficiently to entail their death. The stools will be cut back below ground and the oak standard will be coppiced by the contractor, but it is improbable that re-growth will follow. They were isolated, in good situation and likely to develop into standards.

Presuming that two out of the three stools burnt would have furnished stems of promise, and considering that the average exploitable age of the locality is 100 years, the injury consists in :—

1. A 25 years old oak, the timber of which at 100 years of age would be worth 25 francs.
2. Two stools, the re-growth from which would have produced timber worth 25 francs at the age of 100 years.

In the locality the rate of interest for property of this nature is 4 per cent.*

Injury.

1. The young oak standard would have attained a value of 25 francs. in 100—25=75 years. There is no reason to believe that on cutting back a new promising stem will be obtained, the contrary is more probable in view of the serious derangement at the collar ; consequently, no allowance need be made for the possibility of its being replaced by good re-growth capable of yielding a second-class standard in 75 years. It is not necessary to make any deduction for the coppice which may take its place for this latter will but balance the loss of the branch-wood of the standard, which has not been included in the calculation. The actual loss is, therefore, 25 francs ; but incurred 75 years hence ; discounted to date it becomes :—

(ii)
25 × 0·0528= . . . . 1·32 franc.

2. The loss on account of the stools destroyed is :—

(ii)
2 × 25 × 0·0198 . . . . 0·99 „

The injury to the stools is too severe to encourage hopes of coppice. The plants replacing them will not yield individuals of future promise. Moreover, neither the growth during the first rotation nor the succeeding re-growth need be included here, as they but compensate for the branches which are not taken into account.

*It is advisable to justify the rate adopted in the manner indicated in the course of the work, especially where the damage is considerable.

3. *Cost of replanting.*—This cannot be calculated on the data available in estimates of works of reafforestation which are usually carried out on a large scale. The general expenses, acquisition and transport of plants, or, more simply, their extraction from the forest, hire of labour and time wasted in reaching the work-spot, would be the same as for planting 100 plants; this will swell the cost, which, no longer in proportion, will certainly amount to 4 hours' labour, or . . . . 1·20 francs.

4. *Salvage and cost of cutting back*—These two items will counterbalance.

TOTAL DAMAGE . 3·51 francs.

The indemnity payable by M. N. A. or in default by M. A. B., responsible as contractor, on account of the fire in coupe 22 of the communal forest of Neuilly on the 9th instant, is determined at three francs fifty-one centimes.*

* The omission of all mention of compensation for the grass and dry leaves burnt is remarkable, seeing the minuteness practised elsewhere by the author. *Translator's note.*

Appendix D.

Report on a Fire in Coppice-with-Standards.

This report purposely has been made very full in order to include practically every kind of indemnity that can be claimed in case of fire. In practice, some of them, nearly insignificant, may be omitted.

Dated 1st June 1901.

We, the undersigned , depose :

On this date, at one o'clock at night, a fire occurred in coupe 22 of Chaumont, in the canton of Fays. The fire was started by one of the locomotives of the Eastern Railway Company, which passed over the permanent way along the burnt coupe between 12-30 and 1 ; in all probability, the one drawing the express 10A (from Reims to Dijon), of which the ash-box and funnel habitually allow an abundant escape of glowing cinders and sparks. Moreover, this locomotive has previously more than once set fire to the forest of Chaumont, notably on the 29th March 1898 and 1st May 1899.

The abnormal discharge of burning coal embers can be witnessed whenever the expresses pass, and was on this day particularly observed by pointsman Vuibert of Saxby No. 2. Additional proof is furnished by the fact that the tufts of grass growing at the foot of the stony embankment carrying the permanent way were the first to be burnt, though they are within the boundary hedge and to windward of the forest.*

The railway embankment has an inclination of 45° and is devoid of vegetation. At the foot, along both sides of a very young and incomplete live fence, a belt of a total width of about one metre has been hoed up. This narrow band suffices, as a rule, to catch the fragments of coal, but this day the north wind, blowing with violence, added to the extreme rapidity of the train, caused some cinders to traverse the cleared zone and fall among the grass and dead leaves covering the floor of the forest, to which they set fire.

Pointsman Vuibert at Saxby No. 2, perceiving the smoke, at once ran for assistance. But for his praiseworthy initiative and the generous promptitude of Captain Tanguy, who, on being informed, at once had the fire surrounded by the men of his Company, it is probable that at least 30 hectares would have been burnt. The railway storekeeper likewise made every effort to arrest the progress of the conflagration.

One hectare in coupe 22 of 1895, under coppice-with-standards, was overrun by the fire. The standards have not been affected, but the coppice, composed of oak ·2, beech ·4 and hornbeam ·4, is ruined. It presents a more hopeless prospect than the adjoining coupe of 1894, burnt over under the same conditions on the 29th March 1898, and

* To the report a sketch showing the railway line, the area burnt, the embankment and the direction of the wind should be attached.

which withered on foot three months later. Cutting back is imperative. 25 per cent. of the shoots are so far injured as to be incapable of producing coppice.

A separate special exploitation cannot be prescribed for the area burnt, and it will have to be felled with the remainder of the coupe, which has a total area of 5·32 hectares. In regard to this portion, therefore, there will be disorganisation in the management.

The indemnity is calculated as follows:—

The standards have not suffered; the only loss will be due to a somewhat decreased height increment, since the date of exploitation prescribed by the working plan remains unaltered. We must, therefore, differentiate between the two exploitations, that of the coppice and that of the isolated standards.

Rate of interest for the coppice.—The *ensouchement* in this forest is valued at 220 francs per hectare and the soil at 150 francs. From actual survey it has been ascertained that the standards in coupe 22 occupy one quarter of the total area. The *ensouchement* represented by the coppice has, therefore, a value of $\frac{3}{4} \times 220 = 165$ francs. Similarly the value of the soil under coppice alone is $\frac{3}{4} \times 150 = 112$ francs. After deduction of the revenue realised from minor produce (1·80 francs) the annual charges amount to 1·40 francs per hectare, giving for the coppice alone $\frac{3}{4} \times 1{\cdot}40 =$ 1·05 francs. The capital invested is therefore:

Soil	112	francs.
Ensouchement	165	„
Annual charges capitalised at 3 per cent.	35	„
TOTAL .	312	„

According to the working plan coupe 22 will be felled in 1920, that is to say, when 25 years old. The control books show that coupes in the locality of the same composition and exploited at the same age yielded an average of 85 *stères* of charcoal wood, 15 *stères* of billets and 700 faggots per hectare. Applying the actual market rates, which have fallen since 1889-90, but allowing for reduction in the transport charges owing to the construction to the new export road, the value of such a yield amounts to 332 francs per hectare, as follows:—

85 *stères* of charcoal wood	@ 2 francs per *stère* . . .	170	francs.
15 *stères* of billets	@ 8 francs „ „ . . .	120	„
700 faggots . .	@ 6 francs „ 100 . . .	42	„
	TOTAL .	332	„

The net rate of interest for the coppice is:—

$312\ (1 + x)^{25} = 312 + 332$ whence:

$x = 2{\cdot}94$ per cent. or in round figures 3 per cent.

Rate of interest for the upper storey.—The normal stock of standards appears capable of reproducing itself in perpetuity while yielding the same produce indefinitely. Its absolute estimation is therefore :—

Soil		150 — 112 =	38 francs.
Ensouchement		220 — 165 =	55
Annual charges capitalised @ $5\frac{1}{4}$ per cent.		$0{\cdot}35 \times \frac{100}{5{\cdot}25}$	
Standards	120 new	@ 0·15 = 18	238
	60 2nd-rotation . .	@ 2 = 120	
	10 3rd „ . .	@10 = 100	
		Capital invested .	338 francs.
Revenue	60 2nd-rotation standards	@ 2 = 120	870
	50 3rd „ „	@ 10 = 500	
	10 4th „ „	@ 25 = 250	
		Total Capital value .	1,208 francs.

Rate of interest $= 338\,(1 + x)^{25} = 1{,}208$
whence $x = 5\frac{1}{4}$ per cent.

A similar calculation determines the rate of interest for the whole forest as $4\frac{1}{4}$ per cent.

As the cutting back cannot be carried out for another month, the current year's rise of sap will be entirely lost; the shoots sprouting from June to August have not time to mature in the cold region; it is practically certain that they will be killed off by the first frost. We must, therefore, consider the portion burnt as six years old.

1. *Shrubby weeds.*—The present cutting back and the felling in 1920 amount to two successive curtailed rotations, which, more especially on this calcareous soil, will favour the development of weeds at the expense of the better species. By comparison with similar areas worked on a short rotation, we can conclude that at least one-third of the area will be occupied by these absolutely valueless species. This loss will be calculated in the next paragraph.

2. *Deterioration of the growing-stock.*—One quarter of the growing-stock being too seriously injured to produce any re-growth, the inferiority of artificial plants that will have to be introduced as against coppice-shoots will have to be taken into account. This depreciation will be manifested under three aspects: decreased girth and fewer poles, that is to say, a diminished volume-yield and less valuable material (charcoal wood instead of billets), mediocrity of the new standards due to the weakness and poor development of the shoots.

In the Fays, it is principally between 22 and 25 years of age that the growth passes from the class of charcoal wood to that furnishing billets. Moreover, the dry superficial soil is more unfavourable to the poorly developed root-systems of artificially introduced plants than to those of healthy coppice stocks; the artificial plantation will be over three years behind hand.

When the burnt section comes under the axe, it will be only 19 years old. The stools capable of producing shoots after cutting back form

three quarters of the coppice and will, therefore, produce $\frac{3}{4}$ of the normal yield at that age.

52 *stères* of charcoal wood @ 2 francs = 104
500 faggots . . @ 6 per 100 = 30

134 or $\frac{3}{4}$130 = 100·50 francs.

As for the portion destroyed and replaced by planting, it will be equivalent to a coppice of 16 years :—

25 *stères* of charcoal wood @ 2 francs = 50
600 faggots . . .@6 francs per 100 = 36

86 or $\frac{1}{4}$86 = 21·50 „

Total . 122 francs.

Deduct one-third for the portion invaded by the valueless shrubby weeds :—

$$122 - \frac{122}{3} = 81{\cdot}34 \text{ francs.}$$

But the sale would ordinarily have realised 332 francs at 25 years, the normal age of felling. Thus in 19 years a loss of 332 − 81·34 = 250·66 will be experienced ; discounting to date we get :—

250·66 × 0·5703 . . . . = 142·95 francs.

2. *Replanting.*—The replacing of a quarter of the shoots, the proportion destroyed, will cost—

1,000 oaks.
900 beech.

1,900 plants at 25 francs per 1,000 . . . . = 47·50 „

4. *Loss in height-growth of the standards.*—As the coppice will be felled at 19 years of age, it will not attain its normal height ; consequently, it will not exercise its usual function of natural pruning to the full height of the boles of the standards, it follows that the latter, instead of yielding timber, will furnish only fuel. Examination of adjacent coupes in identical situations shows that the coppice falls short by 1½ metres of its normal height and, therefore, the standards will suffer to the extent of at least 1 metre.

If we apply to the volume of the top log of one metre, of the actually existing standards, the difference between the price per cubic metre for timber and that of fuel, we obtain the loss per tree in each girth class.

At the end of the next rotation the shoots to be reserved as standards will only be 19 years old. The length of their boles will fall short of the normal, and further, natural pruning owing to shade will not have been effective to the same extent as it would during the additional six years, from the 19th to the 25th. When it again operates in the second rotation, at the time the coppice has gained sufficient height, it will be exercised on large branches and will be apt to cause more harm than good. In short, these facts constitute a further source of injury of the same nature and gravity and affecting all the future standards.

Carried forward . 190·45 francs.

Brought forward . 190·45 francs.

The prescriptions for the selection of standards enables us to indicate, with tolerable accuracy, the date on which the standards will be exploited.* Applying the prices per unit we obtain :—

						francs.
For the next	rotation, in	19	years, a loss of			11·31
,, ,, second	,,	44	,,	,,	31·40+ 2·16=	33·56
,, ,, third	,,	69	,,	,,	37·45+ 5·25=	42·7
,, ,, fourth	,,	94	,,	,,	13·36+31·8 =	45·16
,, ,, fifth	,,	119	,,	,,	22·31+58·55=	80·86
,, ,, sixth	,,	144	,,	,,		22·31

These losses, discounted to date at $5\frac{1}{4}$ per cent. for standards, become :—

$$\left.\begin{array}{l} 11·31 \times 0·377 \ =4·26 \\ 33·56 \times 0·1047=3·51 \\ 42·70 \times 0·029 \ =1·24 \\ 45·16 \times 0·008 \ =0·36 \\ 80·86 \times 0·0022=0·18 \\ 22·31 \times 0·0006=0·02 \end{array}\right\} 9·57 \quad ,,$$

5. *Want of vigour in the new standards.*—In spite of the premature felling, the management will be compelled to select standards from the 19 years old coppice at the end of the rotation. The sudden isolation will distort or break a certain number of them, more especially in the portion replanted. The record of windfalls in adjoining private forests exploited at about the same age, and comparison with the shoots of the Fays, enable us to fix the probable casualties at one-third at the least ; normally it is but one-fifth ! The damage on this account is therefore :—

$$(\tfrac{1}{3}-\tfrac{1}{5})120 = \tfrac{2}{15}\ 120 \text{ or } 16 \text{ young standards.}$$

Admitting that, conformably to the usual marking, at each rotation in future half the existing standards are removed and the other half reserved for another rotation :

At the conclusion of the second rotation the loss will consist of 8 second-rotation standards at 2 francs=16 francs.

At the term of the third rotation the loss consists of 4 per cent. third-rotation standards at 10 francs=40 francs.

At the end of the fourth rotation, the loss amounts to 4 fourth-rotation standards at 25 francs=100 francs.

These losses occur 44, 69 and 94 years hence, discounted to date, they are reduced to :—

(ii)

$$\left.\begin{array}{l} 16 \times 0·1047=1·68 \\ 40 \times 0·029 \ =1·16 \\ 100 \times 0·008 \ =0·80 \end{array}\right\} 3·64 \quad ,,$$

Accessory expenditure.

6. *Cutting back.*—For the cutting back of the shoots burnt 3 woodcutters at 3 francs will be required . . . . . 9 ,,

Loss of the soil-covering.

7. *Grass.*—The coupe produced 200 kgs. of dry grass the combustion of which caused a loss of 8·5 per cent. of protein (neglecting other material volatilised) containing 16 per cent. nitrogen, or in all $2 \times 1·36$ kg. The equivalent in artificial manure of the kind indicated in the next paragraph amounts to :—

$1·80 \times 2·72$ . . . . . . 4·90 ,,

Carried forward . 217·56 francs.

* It is advisable to justify these figures by drawing out tables analogous to those in Section 81 ; they are omitted here in order to avoid unnecessary repetition.

Brought forward . 217·56 francs.

8. *Loss of nitrogen.*—The total weight of dry leaves burnt may be taken at 20 quintals, containing 20 kgs. of nitrogen. According to the researches of M. Henry, in 18 months, that is to say, before their final decomposition, they would have fixed a further 17 kgs. Twigs and débris of all kinds consumed, amounted to 24 kgs., of which 16·8 kgs. was nitrogen. To compensate this total loss of 20+17+16·8=53·8 kgs., manure containing the same quantity of the element must be brought on to the area. Organic matter (horn scrapings, dry blood, shavings) of which the cost per kg. of nitrogen contained amounts to 1·89 francs, is alone suitable for the very light, stony soil of the area. Reparation will, therefore, be effected at an expenditure of:—

Cost of manure	53·8 × 1·8 = 96·84	102·84 ,,
Transport and spreading of 416 kgs. of manure on contract	6	

9. *Disappearance of earthworms.*—The drying and hardening of the soil owing to the destruction of the soil-covering, will cause the emigration of earthworms. The resulting loss amounts to at least 2 per cent. of the total increment of the crop, standards as well as coppice; the average revenue is 1,200 francs, giving a rate of interest of $4\frac{1}{4}$ per cent. The loss, however, is suffered 19 years hence. Twenty-four francs discounted to date corresponds to:—

$$\overset{\text{(ii)}}{24 \times 0{\cdot}454} = \quad . \quad . \quad . \quad . \quad 10{\cdot}90 \ ,,$$

10. *Salvage.*—The produce has no saleable value and will be left *in situ*. ......

TOTAL LOSS . 331·30 francs

The indemnity payable by the Eastern Railway Company to the town of Chaumont on account of the fire of the 1st June 1902 in coupe 22 of the Fays, is determined at three hundred and thirty-one francs and thirty centimes.

Appendix E.

REPORT ON A FIRE IN BROAD-LEAVED HIGH-FOREST.

Dated 21st February 1902.

We, the undersigned , depose:

On the 20th instant, at about seven P.M., a fire arose in parcelle A 5 in the State forest of La Garenne, treated as beech and oak high-forest.

The perpetrator remains unknown. Suspicion, however, rests upon the woodcutters at work in the contiguous coupe A 4, sold in 1901 to M. B. L. of Bar-sur-Aube. The following facts have been elicited:

1. The sodden state of the ground, due to the rain of the preceding days, sets aside all idea of mere carelessness on the part of a smoker or sportsman. Moreover, there has been no shooting, and further, a match would not have sufficed to set fire to the soil-covering, for, in spite of the intensity of the flames, which rose to a height of several yards, clumps of grass and patches of dead leaves, which happened to be damper than the rest, remained unaffected. In all probability it could only have spread from a vigorous fire intentionally started and maintained, possibly by children at play, either near the stream forming the western boundary or on the ride between A5 and A4, or simultaneously at both points.*

2. According to the depositions annexed, H. L............., son of the woodcutter P. L.............of Consigny, denies having gone to the spring. This untruth is striking as he goes there every day at least once. The other labourers employed in the coupe saw him there yesterday, and his own sister as well as J. T............, son of woodcutter J. T.............of Clinchamp, deposed that they accompanied him thither on that day. (Exhibit 1.)†

3. On the morning of Friday, the 21st instant, branches of Daphne mezereum, cut the day before, were lying in the centre of the burnt area. Now we have ascertained that the children of these workmen are in the habit of gathering all the Daphne they find. That evening the other woodcutters saw the two L. . . children start in that direction to gather Daphne. (Exhibits 3, 5 and 6.)

4. Yesterday, Thursday, the parents of the two L.............children, having business entailing their absence, enjoined them to remain with their play-fellows, but in this they were not obeyed. (Exhibits 2, 3, 4, 5 and 6.)

5. The charcoal burners S....and P.... saw the L....and T....children lighting fires at several points along the Plateau road (Exhibits 2 and 4). It seems probable that the children amused themselves in alternately lighting fires and gathering Daphne.

* A detailed sketch should be attached to the report.
† Signed depositions must be submitted with the report to the court of enquiry.

6. Lastly, the spot is unfrequented; excepting woodcutters no one passes on week days. The proprietor of the neighbouring mill alone occasionally goes that way to Foulain on Sundays.

The area burnt is 140 metres from coupe A4 under working, that is to say, within ear-shot. Consequently M. B. L......, timber merchant of Bar-sur-Aube, is legally responsible, as laid down by the Court of Appeal (criminal appeal, 10th January 1852 and 8th July 1853).

A slight north-east wind prevented the fire from spreading in that direction, *i.e.*, to the rest of the coupe. Arrived at the stream forming the western boundary, the fire was unable to cross and burnt itself out; otherwise some 30 to 40 hectares would have been destroyed. Actually the fire extended over an area of 50 *ares*, consuming the grass and dead leaves, withering 10-year old shoots of oak and beech and scorching 6 old oak and 10 beech poles sufficiently to make it probable that they will die. The fate of these trees will only be known after the lapse of some months, but in any case planting will undoubtedly be called for to replace young growth.

This parcelle has been under regeneration since 1891; the final felling has just been completed. The saplings are 10 years old.

It is impracticable to treat the area burnt separately, and it must be included in the series of operations prescribed for the remainder of the coupe, which has an aggregate area of 16·57 hectares. Consequently, there will be disorganisation of management.

Among the injured trees, 4 beech (2 of 0·1 m. and 2 of 0·5 m. in girth) are crippled through breakage of their branches; they are useless to the forest, and no allowance need be made for their future production. The trees of future value damaged by the fire are the following:—

Girth:	0·35 m.	0·45 m.	0·50 m.	0·60 m.	1·70 m.	1·80 m.
6 oaks.	2 of 7 m.	2 of 8 m.	—	—	1 of 10	1 of 11
6 beech	—	—	4	2	—	—

In view of the wide interval between these trees there would have been no necessity for a thinning before the end of the rotation of 140 years. The two old oaks, specially preserved as seed-bearers to complete the stocking, would have been felled in four years.

From the statements of yield, the data quoted in the working plan and the control-books, it is observed that the growing-stock in A5 is normal and capable of a sustained yield of:—

At 40	years	a thinning yielding	60 francs.
60	,,	,, ,, ...	120 ,,
80	,,	,, ,, ...	250 ,,
100	,,	,, ,, ...	600 ,,
120	,,	,, ,, ...	800 ,,
140	,,	a seeding felling yielding . .	2,000 ,,
145	,,	a secondary ,, ,, . .	3,000 ,,
150	,,	a final . ,, ,, . .	3,000 ,,

The following calculation gives $2\frac{1}{2}$ per cent. as the rate of interest :—

Material	Soil	150		410 francs.
	Ensouchement	10		
	Regeneration	220		
	Reserved poles	30		
	(i)			
Revenue	60 × 11·814	= 708·8	12,591 ,,	
	120 × 7·21	= 865·2		
	250 × 4·4	= 1,100		
	600 × 2·685	= 1,611		
	800 × 1·639	= 1,311		
	2,000	= 2,000		
	(ii)			
	3,000 × 0·884	= 2,652		
	3,000 × 0·781	= 2,343		
				13,001 francs.

If $2\frac{1}{2}$ per cent. is the correct rate then $480 \times 1{\cdot}025^{140}$ should equal 13,001. Actually the resultant is 13,005, which is very near.

Working with a unit of one hectare, the details of injury caused are as follows :—

1. *Depreciation* due to the permature fellings in the coupe. These, effected 10 years too soon, will realise less; the loss is shown in the following statement :—

Revenue realised.	Loss.
30	60 — 30 = 30
80	120 — 80 = 40
180	250 — 180 = 70
480	600 — 480 = 120
600	800 — 600 = 200
1,700	2,000 — 1,700 = 300
2,650	3,000 — 2,650 = 350
2,650	3,000 — 2,650 = 350

These losses will be incurred in 30, 50, 70, 90, 110, 130, 135 and 140 years respectively. Discounted to date they become :—

(ii)		
30 × 0·477	= 14·31	100·20 francs.
40 × 0·291	= 11·64	
70 × 0·178	= 12·46	
120 × 0·108	= 12·96	
200 × 0·0661	= 13·22	
300 × 0·0403	= 12·09	
350 × 0·0357	= 12·50	
350 × 0·0315	= 11·02	

2. *Cutting back.*—Three days woodcutter's wages at 3 francs . 9 ,,

3. *Re-stocking* involved by the removal of seed-bearers. The existing shoots have been so far damaged that a large proportion will not throw out new shoots; moreover, they are too young to produce promising growth and, finally, the majority are beech, the shoots of which are liable to die off in the absence of the shelter essential to their welfare. For these reasons, not more than one quarter of the normal natural regeneration can be counted upon. Seven thousand and five hundred plants at 25 francs per 100 must be planted . . . . . . = 187·50 ,,

Carried forward . 296·70 francs.

Brought forward . 296·70 francs.

4. *Loss of nitrogen*—The total weight of dried leaves burnt is 16 quintals. They contained 16 kgs. of nitrogen. According to M. Henry's observations, in 18 months, *i.e.*, before they decompose, they would have fixed 13·6 kg. more. The twigs and débris of all kinds consumed weighed one ton, containing 7 kg. of nitrogen.

To compensate this loss aggregating 36·6 kgs., manure containing the same quantity of the element must be brought on to the soil.

The soil is of average compactness and calcareous; sulphate of ammonia is suitable. Its proportion of nitrogen is 20 per cent. and hence :—

$36{\cdot}6 \times \frac{100}{20} = 183$ kgs. will be required.

The indemnity for this item is therefore :—

183 × 0·35 . . . . =	64·05 }	69·05 „
Transport and spreading on contract . .	5 }	

5. *The disappearance of the soil-covering* will result in the emigration of the earthworms, the drying and hardening of the surface soil, in short, in serious obstruction to the development of the growing-stock. This detriment will amount to at least 2 per cent. of the total increment. The loss (251·8) will, however, only be felt in 130 years; discounted to the present moment it becomes :—

251·8 × 0·0403 . . . . . = 10·15 „

375·90 francs.

Indemnity for the portion burnt (½ a hectare) —

½375·90 . . . . = 187·95 francs.

6. *Salvage.*—200 faggots. Unsaleable . . . .

187·95 francs.

Eventual loss.

7. *Depreciation* due to the premature removal of promising growth :—

4 oaks which in 130 years would have realised 60 francs each . . . . . . = 240 francs.

6 beech which in 130 years would have fetched 30 francs each . . . . . . = 180 „

420 francs.

Discounted to date :—

(ii)
420 × 0·0403 . . . . . = 16·92 francs.

8. Prejudice on account of loss of seed which would have been borne by the two oak reserved as seed-bearers, estimated by comparison with the cost of an equivalent plantation of 100 oaks . . . . 2·20 „

9. The trees which have not been included among those of future promise have a saleable value as follows :—

Carried forward . 19·12 francs. 187·95 francs.

Brought forward .		19·12 francs.	187·95 francs.
2 oaks at 50 francs (same value now as in 4 years) . .	100		
4 beech at 50 francs (same value now as in 4 years) . . .	8		
The forced sale will result in failure to obtain the full value, a loss of 30 per cent. should be expected		32·40	
		51·52	
10. *Salvage.*—Deduct the amount realised by the sale of other poles		12	
			39·52 francs.
		TOTAL .	227·47

The total damage caused to parcelle A5 of the State forest of La Garenne by the fire of the 20th February 1902, is determined at two hundred and twenty-seven francs and forty-seven centimes, of which 187·95 francs present and 39·52 prospective and subject to confirmation within a few months.

Appendix F.

REPORT ON THE BURNING OF A PINE FOREST.

Dated 22nd March 1902.

We, the undersigned , depose :

At nightfall on the 20th instant, a fire broke out in the communal forest of Condes in the Combe-Bricard Canton, bearing a 40-year old pine forest. The alarm was first given at about 8 o'clock by P. F., an inhabitant of Condes, who noticed a glow in the direction of the forest. The mayor and the forest guard immediately organised relief, but the darkness prevented promptitude and increased the difficulty of rapid movement over the steep slopes covered with rocks and rolling stones. By the time suppressive measures had been started the fire was already well developed. Thanks to the lines cleared of all inflammable material by the forest department since the close of winter, the fire was mastered at half past eleven. The growth completely killed in coupe 4 must be exploited without delay before the material deteriorates, and also to prevent the increase of wood-boring insects, which might subsequently invade the whole forest.

The disaster would appear to have originated through the negligence of a sportsman by the agency of a burning gun-wad. P. A., road-mender of Brethenay, has deposed (Exhibit 1*), that two of his neighbours, J. B. and L. M. of Brethenay, told him they had seen red-tinted smoke towards Combe-Bricard at about seven the day before yesterday evening and commented on the imprudence of sod-burning (*écobuage*) at this season. We have ascertained, however, that for several days, no kiln for sod-burning has been started, nor has any fire been lit by either herdsmen or tramps in the vicinity of the forest. The glow seen near the southern boundary was indeed that of the fire under report at its inception. From the direction of the wind and the extent already burnt over when the first helpers reached the spot, it is certain that the fire started on the southern boundary, near the angle known as "*La Grande Borne.*"† A. T., woodcutter of Condes (Exhibit 2), walked along the "postman's path" at a distance of 10 metres of *La Grande Borne* at 6 P.M., and neither saw, heard nor smelt any indication of the fire, which, therefore, must have started between 6 and 7 o'clock in the evening.

Now, at this hour, M. E. C.... of Chaumont was shooting in this locality. M. E. C.... is joint-lessee of the shooting in the Condes wood and in the private forest belonging to M. B...., which is separated from the communal forest merely by a cleared belt 100 metres broad. A. C...., a shepherd of Brethenay (Exhibit 3), saw M. E. C....'s dog, at about 5 o'clock, ranging alternately in the two woods, and half to three quarters of an hour later, when returning with his flock, he heard several calls.

The day before yesterday evening, M. P. V... ..., ironmonger of No. 7, Rue Neuve, Chaumont, when returning to town at 7 o'clock, met M. C.

* The depositions, duly attested, must be attached to the report.
† A detailed sketch must be attached to the report.

at the beginning of the Faubourg de la Maladière (Exhibit 4). The latter, who carried a net which appeared to contain a bird, was walking very rapidly. When questioned as to his sport he replied evasively and as if vexed and finally stated that he had shot a woodcock at Choignes. The witness was surprised at his answer as he thought he had seen M. C. ... on the Combe-Bricard road. Moreover, Choignes is not a favourable locality for woodcock and finally, to return thence through the Maladière doubles the distance and entails a very considerable detour, which it did not seem likely that M. C....... would care to face for he seemed tired. His curiosity roused by this reticence, M. V.......walked alongside observing his companion with interest. Shortly, he noticed that the bottom of the latter's coat was damaged ; thinking that he had met with an accident, he remarked on it adding: "You smell of burning." At these words, M. C.......uttered an exclamation and continued hurriedly : "Not at all! What an idea! You are mistaken, absolutely mistaken!" He then wheeled abruptly down the next turning to close the conversation, though it was not the shortest way to his residence. This peculiar behaviour impressed M. V......., and the same evening he imparted the story to others and commented on M. C.'......s eccentricity and lack of courtesy. It was one of his auditors who repeated his words to us and placed us in communication with him.

No other sportsman is reported to have returned to Chaumont, or any of the surrounding villages, with game of any kind, on Thursday evening. The locality is little frequented; besides the shepherd of Brethenay, none pass there but a few woodcutters and sportsmen. Everything pointing to the fire being caused by a burning gun-wad, we returned to the neighbourhood of *La Grande Borne* to search afresh over the space cleared by the fire. The soil had been much disturbed by the comings and goings during the night. Turning over the superficial layer and examining it in detail, at 11 metres from the boundary of the communal forest and 13 metres from the *Grande Borne* (sketch attached), we came upon an empty 16-bore centre-fire cartridge-case white with blue and red marbling. The base is impressed M. C.; Fabre, 16, Rue Réaumur, Paris. The lines and grooves on the rim form a pattern; the copper shows no trace of oxydisation such as would be present had it remained for several days exposed to moisture and in contact with the soil; the free end of the cardboard is striated within with scratches and excoriations, due, apparently, to a characteristic defect in the turn-over machine. They would probably suffice to identify the machine employed and consequently the sportsman.

Stimulated by these coincidences, we endeavoured to secure details of M. C.'s bag. We were shown the woodcock shot on the 20th instant. The tips of several feathers are missing, having been pulled off; the broken ends are not so clean as they would be had they been bitten off by a dog. The extremity remaining has a reddish tinge, as if singed.

All these facts seem to inculpate M. C......., but an absolute personal proof was still wanting to establish a definite conviction. Though we hardly hoped to obtain anything on a ground already closely searched, we nevertheless returned to the locality on the afternoon of the 22nd.

An old willow stands on the slope of the bank bordering the coupe, 14 metres from the *Grande Borne*. It has been pollarded and its fair-

sized trunk is hollow. The wind being in the opposite direction, this tree was not touched by the fire. Further, the rescue party did not cut its branches for beating out the fire, for, at the time of its arrival on the scene, the line of fire had already reached some distance from the boundary, and the helpers resorted to the nearest trees. Consequently, the crown of the willow should be intact and green; some of the branches, however, had been cut and were found lying in the forest in the angle where the fire started. On a closer inspection we found a withered twig, apparently growing out of the central hole of the trunk. It was detached, however, and came away readily in the hand. At the end hung an open knife, the blade of which was jammed in the wood. The knife is of better make than those usually employed by peasants; moreover, none of the men who assisted in putting out the fire has lost a knife. Is it not probable that it belongs to M. C......., who overlooked it in his haste to seize the willow branches nearest to his hand, in order to put out the flames kindled by his shot, in the midst of which struggled the bird he had wounded? Finding himself unable to master the conflagration and exhausted by violent exertion lasting some twenty minutes, he left hurriedly, pursued by the apprehension of his responsibility. At least this hypothesis is extremely plausible!

To sum up: It appears very probable, if not certain, that the fire which occurred in the forest of Condes between 6 and 7 on the evening of the 20th instant, was caused by the burning wad discharged from the gun of a sportsman; and there is strong presumption that M. E. C......., merchant, of Rue Nicholas, Chaumont, is the sportsman in question. In view of the facts presented above, the truth will be completely elucidated by an enquiry into the conditions of time and place of his shooting the woodcock and burning his coat, and an examination of his stock of cartridges. If the knife found belongs to him, the proof will be overwhelming. This portion of the enquiry, however, is in the competence of the Court alone.

Coupe 4, extending over 1·4 hectares, was homogenous throughout and consisted of 40-year old Scotch pine; its conditions of vegetation and density were normal for growing-stocks of that species in the locality, under the same rotation of 60 years. The conditions of growth of pine woods in the Haute-Marne are well understood. At 40 years of age they contain about 1,770 stems per hectare. Enumeration of the material burnt shows 2,450 pines or 1,750 per hectare. Possibly, being somewhat less crowded, they may be better developed than in more completely stocked woods, but, to be on the safe side, we propose adopting the usual prices.

Enumerations, records of yields and control books, checked by comparison with similar growing-stocks in the neighbourhood, prove that coupe 4 can yield the following material:

At 12 years, a thinning out of	1,200 trees, worth	. . . .	4	francs.
„ 20 „ „ „	860 „	. . . .	8	„
„ 28 „ „ „	630 „	. . . .	35	„
„ 36 „ „ „	600 „	. . . .	175	„
„ 44 „ „ „	430 „	. . . .	552	„
„ 52 „ „ „	310 „	. . . .	625	„
„ 60 „ a final felling	872 „	. . . .	2,333	„

On the average, there are 20 trees per hectare more than actually existed in coupe 4; consequently, at the next thinning 20 trees less would have been removed in order to bring the growing-stock back to the normal and the outturn would have been $552-26=526$ francs. This is the only modification necessary.

After each final felling, an outlay of 110 francs for artificial re-stocking has to be met. The annual expenditure amounts to 4·5 francs. The rate of interest is 5 per cent.

Soil, valued according to its fertility by comparison with adjoining lands	. . . .	60	francs.
Material { Seedlings, estimated according to the cost of a plantation		110	,,
Material { *Ensouchement*	. . . .	33	,,
Charges	. . $4{\cdot}5 \times \frac{100}{5}$ . . . . . =	90	
	Capital invested	293	,,

(i)

$$
\text{Revenue} \quad \left\{ \begin{array}{rcrcr} 4 & \times & 10{\cdot}401 & = & 41{\cdot}6 \\ 8 & \times & 7{\cdot}04 & = & 56{\cdot}4 \\ 35 & \times & 4{\cdot}765 & = & 166{\cdot}8 \\ 175 & \times & 3{\cdot}225 & = & 564{\cdot}4 \\ 526 & \times & 2{\cdot}183 & = & 1148{\cdot}3 \\ 625 & \times & 1{\cdot}4775 & = & 923{\cdot}5 \\ 2{,}333 & - & 110 & = & 2{,}223 \end{array} \right\} \quad \begin{array}{l} 5{,}124 \\ \\ 5{,}417 \text{ francs.} \end{array}
$$

The resultant of $263 \times 1{\cdot}05^{60}$ corresponds to 4·98 per cent.; we can, therefore, accept the rate of 5 per cent.

Having been entirely burnt, the coupe cannot be assimilated with any area of the same age in the forest of Condes. After re-stocking when its normal date of exploitation falls due, which will be in 20 years, it will not be fit for cutting; felling, therefore, will have to be postponed until it attains the lowest commercial age, which will be at about 40 years of age; consequently, it will only regain its place in the order of the coupes, at the end of two rotations. This restitution of the regular order is complicated and entails a double loss, for 40-year old growing-stocks fall far short of those 60 years old in quantity as well as quality. The working-plan, however, comes under revision at the close of the current decade, or in 8 years' time, it will be more simple, therefore, to renumber it in the new one according to its actual age after re-stocking.

The damage will now be estimated as follows :—

1. *Value of growing-stock.* It is equivalent to the capital value of the pine forest at 40 years of age, less the amount of capital invested. The formula is :—

$$
C = \frac{4 \times 1{\cdot}05^{28} + 8 \times 1{\cdot}05^{20} + 35 \times 1{\cdot}05^{12} + 175 \times 1{\cdot}05^{4} + 526 \times 1{\cdot}05^{56}}{1{\cdot}05 - 1}
$$
$$
+ \frac{625 \times 1{\cdot}05^{48} + 2{,}223 \times 1{\cdot}05^{40}}{1{\cdot}05^{60} - 1}
$$

This gives :—

		(i)				
4	×	3·92	=	15·7		
8	×	2·653	=	21·2		
35	×	1·796	=	62·9		
175	×	1·2155	=	212·7		
526	×	15·367	=	8,083		
625	×	10·401	=	6,500·6		
2,223	×	7·04	=	15,649·9		
					(iii)	
				30,546	× 0·05656	= 1,727·70
						— 293
						1,434·70 francs.

2. *Re-stocking* to be effected at once; failures must be taken into account; they can be estimated according to the customary results in the locality. The complete re-stocking will require 1,100 plants at 20 francs per 1,000 . . . . = 220 „

3. *Disappearance of the broad-leaved underwood.*—The broad-leaved undergrowth forming a lower storey under the canopy of the conifers, played a most important, if not indispensable, part, from a sylvicultural point of view. Apart from any future intrinsic value, it prevented the formation of turf, corrected the excessive acidity of the soil due to the coniferous needles, and its shelter ensured the freshness essential to vegetation and the regular decomposition of the soil-covering. Re-stocking, which would have been an easy matter under its protection, will now be delayed by excessive casualties. The sum of these adverse influences causes a distinct retardation of growth, resulting in a loss of two years' increment.

$2 \times \frac{5,124}{60} = 170·8$, which loss is experienced 60 years hence; discounted to date it becomes . 170·8 × 0·0535 (ii) = 9·10 „

4. *Cutting back* of the leafy undergrowth, 2 days' wages @ 3 = 6 „

5. *Loss of nitrogen.*—The weight of dry pine-needles burnt can be estimated at 34 quintals. They contained 81 kgs. of nitrogen; before their final decomposition in 18 months, they would have fixed 7 kgs. more. The twigs and débris of all kinds destroyed, weighed 22 quintals, of which 15·4 kgs. was nitrogen. In addition, there were 4 quintals of heather and 2 of moss, containing respectively 5 and 2·8 kgs. of nitrogen. To compensate the total loss of 91·2 kgs. of that element, manure containing the same quantity must be brought on to the area. The shallow soil overlying a fissured mineral stratum, demands an organic fertiliser (horn scrapings, dried blood, shavings) which costs 1·80 francs per kg. contained. The indemnity will therefore be :—

Purchase . . .	91·2 × 1·80 =	164·16	174·16 „
Transport of 700 kgs. of manure and spreading, on contract		10	
	Loss per hectare .		1,843·96 „
Loss for the whole coupe . . .	1,843·96 × 1·4 =		2,581·54 „

6. *Additional accessory indemnities.*—At the time the fire was being got under control, articles of clothing were torn or burnt, tools were lost, and slight wounds requiring attention were incurred. The sundry charges on this account have been fixed by the Mayor at 70 francs, which is a very moderate computation 70

Carried forward ... 2,651·54 francs

Brought forward ...	2,651·54	francs.
7. *Rectification of the working plan records, plan of operations, etc.*—This has to be carried out, free of charge, by forest officers, and is mentioned here for the sake of completeness .	...	
8. The commune had a small pleasure park laid out in the coupe, which was much frequented on Sundays and holidays. It consisted of an avenue of 40 spruce trees, 65 years old, a circular court round a lime tree of unknown age (between 140 and 180 years), and a circular walk flanked by 23 eighty-year old sycamores. All these trees are either killed outright or too seriously injured for further preservation. Damage involved falls under two heads:		
From the æsthetical point of view the loss is irreparable. The promenade has disappeared, and its character cannot be restored in less than fifty years. The villagers set great store by it. The Mayor has been sounded; he intends claiming damages to the extent of at least 200 francs. We propose, therefore, to accept this figure, while not prejudicing the right of the community to claim a higher sum	200	"
It is not inequitable to make allowance for the sentiments of those concerned in a valuation of this nature.		
As regards material damage, the value of the 40 spruce is estimated at 240 francs. In 65 years, *i.e.*, at 130 years of age, they would have been worth 1,600 francs. Admitting that they are replaced by the same number of individuals of same species, the loss in 65 years will amount to 1,600—240=1,360, representing at $2\frac{1}{2}$ per cent. (applicable to such ornamental woods), at the present date, a sum of :—		
1,360 × 0·201 (ii) =	273·40	"
Owing to the shortness of their boles, the sycamores were of but little value (166 francs); in 40 years they would have furnished logs fit for planks, which would have doubled their value. Admitting their replacement by the same number of the same species, worth 60 francs in 40 years, the loss will amount to 332−60=272; discounted for 40 years:		
272 × 0·372 (ii) :	101·20	"
The lime tree need not be considered as it has no saleable value.		
9. Cost of replanting the spruce and sycamores on contract .	6	"
	3,232·14	francs
10. *Salvage.*—Deduct the sale price of the trees burnt:		
2,450 pines . . . . . . 900; 40 spruce, 23 sycamores 300	1,200	"
Net loss	2,032·14	francs

The total indemnity on account of the injury caused by the fire of the 20th March 1902, in coupe 4 of the communal forest of Condes, is determined at two thousand and thirty-two francs and fourteen centimes.

Note.—It may be noted that no deduction was made from the value of the pine growing-stock on account of the area occupied by the pleasure park. Apparently that area has been excluded from the coupe, as the coupe is said to have been homogeneous throughout, but no definite statement of such exclusion is made. *Translator's note.*

Appendix G.

INDENT FOR CREDIT ON ACCOUNT OF CHARGES FOR CUTTING BACK AFTER A FIRE.

Dated the 25th May 1902.

We, the undersigned , depose:

On the 4th March last, a fire, reported on the same day, burnt over 80 *ares* of coppice in coupe 12 of the communal forest of Chamarandes, canton des Coteaux. At the time the necessity for cutting back was doubtful, but at this date the coppice is manifestly ruined. Cutting back is urgent in order not to lose the current year's rise of sap altogether. The cost will amount to 33 francs, *viz.*, 11 days' woodcutter's wages at 3 francs. We have, therefore, the honour to request the very early grant of a credit of 33 francs against the budget of the commune of Chamarandes, for the execution of the work of cutting back the 80 *ares* of coppice burnt in the Canton des Coteaux, under the direction of the Forest Department.

(Sd.) X——

Estimate for the work of cutting back to be carried out in 1902 in the communal forest of Chamarandes.

Item 1.—Cutting back over 80 *ares* of coppice burnt:

11 days' wages of woodcutters, inclusive of time lost and supply of tools, at 3 francs per day . . . . . . 33 francs.

Total of present estimate, 33 francs.

Y., the 25th May 1902.

(Sd.) X——

Appendix H.

Note.—This report must be written on stamped paper and must be devoid of erasures and superimpositions.

Judicial valuation.

LITIGATION PENDING BETWEEN MM. DAGUET AND TERRASSE *re* INJURY CAUSED TO THE FOREST OF NOTA BELONGING TO M. DAGUET BY A FIRE ORIGINATING IN M. TERRASSE'S TIMBER YARD.

Report on the valuation.

9 A.M., 10th May 1902.

We, the undersigned: Gillot, Sub-Inspector of Forests; Ronot, Surveyor; Varin, Road Overseer; all three residing at Chaumont.

Under the ordinance of the President of the Civil Court of Chaumont, under date of 30th April, 1902, have been directed to:

Ascertain the origin of the fire which broke out in the forest of Nota, belonging to M. Daguet;

Determine whether the fire spread from M. Terrasse's timber yard;

Institute in this connection all necessary enquiries;

Estimate the injury suffered by the plaintiff and the indemnity that may be due to him;

Formally exempted from the oath by the said ordinance (or else "being duly sworn"), after issuing due notice to all parties concerned,* we resorted, on the date and hour stated, to the locality mentioned, where we found:

1. The plaintiff, M. Daguet of Chaumont, who requested us to proceed with the valuation and signed without prejudice.

(Signed) DAGUET.†

2. M. Henriot, attorney and solicitor for M. Terrasse, merchant of Neuilly. M. Henriot stated that he wished to raise no objection to the proceedings, reserving to himself the power to make such requisitions and observations as he would deem advisable during their course; he has signed with full reservation.

(Signed) HENRIOT.

3. M. Lamarche, attorney and solicitor for M. Finot of Paris, has failed to appear in spite of the summons sent to him on the 4th April through M.X., attorney of Paris.‡

---

* The parties are summoned verbally at the time of taking the oath before the magistrate, but if the swearing is dispensed with or the parties are not present at the time, the notice is given by letter or other means.

† The signature of the parties is indispensable for a formal opening of the enquiry.

‡ In order to make the example more complete, we suppose that a third party has been drawn in by the defendant, M. Terrasse, in the hopes of shifting or diminishing the responsibility. Beyond the formalities in the opening of the enquiry the appraiser need give no attention to this third party.

We then proceeded to take down the statements and verifications prescribed by the abovementioned ordinance, and, furnished with the information obtained, we have drawn up our report as follows:

Situation of the forest of Nota.—*Full description including methods of clearance, transport and markets.*

Situation of M. Terrasse's timber yard.—*Complete description, particularly with regard to possible access from the yard to the forest.*

* * * * * *

Origin of the litigation.—*Enquiry into the cause of the fire.*

The appraisers must be careful not to accuse M. Terrasse personally or to put him on his defence, even when admitting that the fire arose from his own act. Their duty consists solely in making the necessary technical enquiries to ascertain:

1. Whether under certain conditions of heat, situation, wind, proximity of fermentable matter (oily rags), etc., the lignite containing sulphurous pyrites recently extracted from the mine and heaped in M. Terrasse's yard might have spontaneously burst into flames and spread the fire to the saw-dust and waste wood lying there.

2. Whether sparks thrown off from this conflagration could have set fire to the forest of Nota, 40 yards distant. The appraisers must restrict themselves to accumulating scientific and experimental proof, which will place the court in a position to form an opinion and draw its own conclusions.

They are at liberty to examine witnesses, but they must not name any of them in the report, nor may they suggest that their conviction is based solely on such depositions. The results of the investigation must be stated without any indications of the intermediaries who may have influenced the impressions. The observations obtained and verified must be stated as if they were original. Nevertheless, when necessary, they may support their convictions by quoting *public opinion* and *trustworthy information received*, corroborating the latter by known facts.

Technical investigations.—*Analysis of the working plan.—Data of the productiveness of the forest.—Measurement of the volume of material destroyed, etc.*

Valuation of damage.—*Estimate of quantity and money-value of the wood burnt.—Appraisement of prejudice involved by subsidiary injuries (sundry disturbances).*

Conclusion.

* * * * * *

Statements and requisitions of the parties.—Before closing our report we, the undersigned appraisers, on the 3rd September, 1902, invited the parties interested to formulate any statements or requisitions they might desire to place on record.* In reply, the plaintiff, M. Daguet, declared that he had nothing further to bring forward.

M. Lamarche, attorney and solicitor representing M. Finot of Paris, expressed his intention of remaining unrepresented.

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* This invitation may be made at the beginning of the investigation and need not thereafter be renewed. The appraisers are not bound to read out their report to the parties, nor need they consult them. If they do consult them and once more invite their opinions before closing the enquiry, it is for the sake of information and to remove all ground for complaint.

M. Henriot, attorney acting on behalf of M. Terrasse of Neuilly, stated : (*Here copy word for word the statement of the attorney which he must submit in writing*).

* * * * * *

And the said M. Henriot, after reading over, has signed, reserving all rights of M. Terrasse, especially against MM. Daguet and Finot.

We, the undersigned appraisers, after accepting all the above statements, proceeded to take all the depositions and verifications demanded by M. Terrasse, and, armed with all the information obtained by us, we have completed our report as follows, dealing consecutively with each of the requisitions made.

1. *Develop, comment on, refute, if necessary, M. Henriot's allegations ; in short, answer, step by step, all the new objections raised.*

2. ....

In short, the statements and requisitions presented before us by M. Henriot, on behalf of M. Terrasse, on the 3rd instant, put forward no new facts and are not of a nature to invalidate or alter the preceding portion of our report. Consequently, there is no reason for us to depart from our first conclusions.

At our invitation, all the parties, with the exception of M. Finot, still absent in spite of the summons delivered to him on the 25th September 1902, *vide* the writ of M.G......., bailiff of Paris, registered on the 27th instant, appeared in the office of M. Gillot, one of the appraisers, at this date and hour, and they declared that they had nothing to add to the remarks already made before us.

And the parties appearing have signed.*

(Signed) DAGUET. (Signed) HENRIOT.

We, the undersigned appraisers, thereupon immediately closed the present report on the 30th September one thousand nine hundred and two, at three P.M.

(*Signature of the three appraisers.*)

Registered at Chaumont the . . . .

Costs of the investigation.

The appraisers are due :—

Stamped paper for the report : 6 sheets @ 1·20 fr.	7·20 fr.		
Registration of the report. ,, ,,	3·75 ,,	20·95 francs.	
Purchase of lignite, rags, etc., for experiments .	10 ,,		

To M. Gillot :—

16	11 Sessions † for enquiries and experiments in the locality (1st portion of the report, prior to the 3rd September).	96	
	5 Sessions (2nd portion, depositions of 3rd September on the formal requisition of M. Henriot) .		198
	2 Sessions for discussion of the terms of the report .	12	
15	10 Sessions for drafting the report (1st part) .	90	
	5 Sessions for drafting the report (2nd part) .		

* This signature is not required by law ; it is simply a precaution against future complaints and disputes.

† The French word is *vacation*, which signifies a sitting of 3 hours, and is remunerated at 6 francs—one day cannot comprise more than 4 sittings.

To M. Ronot :—

6 Sessions for enquiries and experiments . . .	36	48	francs.
2 Sessions for discussion of the terms of report . .	12		

To M Varin :—

5 Sessions for enquiries and experiments . . .	30	48	„
2 Sessions for discussion of the terms of report . .	12		
1 Session for deposition of the report in the record office .	6		

This bill of charges follows the report to which it should remain attached. It need not be signed.

TABLE I.

Giving the expansion of the factor $(1+t)^n$ at different ages n and for different rates t, for 1 unit.

This table gives the factor by which sums placed at compound interest must be multiplied in order to obtain their value, capital and accumulated interest, at the expiration of a number of years n.

$$C = V\ (1 + t)^n.$$

By deducting the unit the interest alone results:

$$R = V\ [(1 + t)^n - 1].$$

Note 1.—The table has been taken up to 9 per cent. only as it is easy to calculate the figures for the next two units 10 and 11. Should occasion arise for their employment, it will be only for short periods and there will be no difficulty in multiplying with such simple figures as 1·1 or 1·11.

Note 2.—The rates most required are 2, $2\frac{1}{2}$, 3, ... 5; it therefore serves little purpose to overburden the tables with intermediate figures that will rarely be used. When, exceptionally, the rates $2\frac{1}{4}$, $2\frac{3}{4}$, $4\frac{1}{4}$, etc., are required, they can be obtained without the use of logarithm tables, by taking the mean between the next highest and next lowest factors. This is not absolutely correct, but is sufficiently approximate.

Thus, the factor for $3\frac{1}{2}$ in 15 years is . 1·675
„ that for 4 in 15 years is . 1·801

By interpolation the factor for $3\frac{3}{4}$ works out at $\dfrac{1·675-1·801}{2} = 1·738$

The exact figure is 1·737, a very slight deviation indeed.

Note 3.—Practically, one has rarely to calculate interest for over 150 years. However, should occasion arise, the intermediate figures can be readily worked out; it is sufficient to multiply the factors of two periods which, added together, equal the age for which the factor is sought.

Thus, the factor for 159 years is obtained by multiplying the factor of 150 by that for 9, or those of 80 and 79.

Example.—At 3 per cent. the factor of 159 years is . 109·931

Now, calculated as above we get:

Factor of 100 (19·219) × factor of 59 (5·72) = 109·932
or factor of 80 (10·641) × factor of 79 (10·331) = 109·932

TABLE I.

Years.	RATES. 1 %	1 1/2 %	2 %	2 1/2 %	3 %	3 1/2 %	4 %
1	1·01	1·015	1·02	1·025	1·03	1·035	1·04
2	1·02	1·03	1·04	1·051	1·061	1·071	1·082
3	1·03	1·046	1·061	1·077	1·093	1·109	1·125
4	1·041	1·061	1·082	1·104	1·125	1·147	1·17
5	1·051	1·077	1·104	1·131	1·159	1·188	1·217
6	1·061	1·093	1·126	1·16	1·194	1·229	1·265
7	1·072	1·11	1·149	1·189	1·23	1·272	1·316
8	1·083	1·126	1·172	1·218	1·267	1·317	1·369
9	1·094	1·143	1·195	1·249	1·305	1·363	1·423
10	1·105	1·16	1·219	1·28	1·344	1·411	1·48
11	1·116	1·178	1·243	1·312	1·384	1·46	1·539
12	1·127	1·196	1·268	1·345	1·426	1·511	1·601
13	1·138	1·214	1·294	1·378	1·468	1·564	1·665
14	1·149	1·232	1·319	1·413	1·513	1·619	1·732
15	1·161	1·25	1·346	1·448	1·558	1·675	1·801
16	1·173	1·269	1·373	1·484	1·605	1·734	1·873
17	1·184	1·288	1·4	1·522	1·653	1·795	1·948
18	1·196	1·307	1·428	1·56	1·702	1·857	2·026
19	1·208	1·327	1·457	1·599	1·753	1·922	2·107
20	1·22	1·347	1·486	1·639	1·806	1·99	2·191
21	1·232	1·367	1·516	1·68	1·86	2·059	2·279
22	1·245	1·388	1·546	1·722	1·916	2·131	2·37
23	1·257	1·408	1·577	1·765	1·974	2·206	2·465
24	1·27	1·429	1·608	1·809	2·033	2·283	2·563
25	1·282	1·451	1·641	1·854	2·094	2·363	2·666
26	1·295	1·473	1·673	1·9	2·157	2·446	2·772
27	1·308	1·495	1·707	1·948	2·221	2·532	2·883
28	1·321	1·517	1·741	1·996	2·288	2·62	2·999
29	1·334	1·54	1·776	2·046	2·357	2·712	3·119
30	1·348	1·563	1·811	2·098	2·427	2·807	3·243
31	1·361	1·586	1·848	2·15	2·5	2·905	3·373
32	1·375	1·61	1·884	2·204	2·575	3·007	3·508
33	1·389	1·634	1·922	2·259	2·652	3·112	3·648
34	1·403	1·659	1·961	2·315	2·732	3·221	3·794
35	1·417	1·684	2	2·373	2·814	3·334	3·946
36	1·431	1·709	2·04	2·432	2·898	3·45	4·104
37	1·445	1·735	2·081	2·493	2·985	3·571	4·268
38	1·459	1·761	2·122	2·556	3·075	3·696	4·439
39	1·474	1·787	2·165	2·62	3·167	3·825	4·616
40	1·489	1·814	2·208	2·685	3·262	3·959	4·801

TABLE I.

Years.	RATES.						
	4 1/2 %	5 %	5 1/2 %	6 %	7 %	8 %	9 %
1	1·045	1·05	1·055	1·06	1·07	1·08	1·09
2	1·092	1·102	1·113	1·124	1·145	1·166	1·188
3	1·141	1·158	1·174	1·191	1·225	1·26	1·295
4	1·192	1·215	1·239	1·262	1·311	1·36	1·411
5	1·246	1·276	1·307	1·338	1·402	1·469	1·539
6	1·302	1·34	1·379	1·418	1·501	1·587	1·677
7	1·361	1·407	1·455	1·504	1·606	1·714	1·828
8	1·422	1·477	1·535	1·594	1·718	1·851	1·992
9	1·486	1·551	1·619	1·689	1·838	1·999	2·172
10	1·553	1·629	1·708	1·791	1·967	2·159	2·367
11	1·628	1·71	1·802	1·898	2·105	2·332	2·58
12	1·696	1·796	1·901	2·012	2·252	2·518	2·813
13	1·772	1·886	2·006	2·133	2·41	2·719	3·066
14	1·852	1·98	2·116	2·261	2·578	2·937	3·342
15	1·935	2·079	2·232	2·397	2·759	3·172	3·642
16	2·022	2·183	2·355	2·541	2·952	3·426	3·971
17	2·113	2·292	2·485	2·693	3·159	3·7	4·328
18	2·208	2·407	2·622	2·855	3·38	3·996	4·717
19	2·308	2·527	2·766	3·026	3·617	4·316	5·142
20	2·412	2·653	2·918	3·208	3·87	4 661	5·604
21	2·52	2·786	3·078	3·4	4·141	5·034	6·109
22	2·634	2·925	3·248	3·604	4·431	5·436	6·658
23	2·752	3·071	3·427	3·821	4·741	5·871	7·258
24	2·876	3·225	3·615	4·05	5·073	6·341	7·911
25	3·005	3·386	3·814	4·293	5·428	6·848	8·623
26	3·141	3·556	4·024	4·55	5·808	7·396	9·399
27	3·282	3·733	4·245	4·822	6·214	7·988	10·245
28	3·43	3·92	4·478	5·112	6·649	8·627	11·167
29	3·584	4·116	4·724	5·418	7·114	9·317	12·172
30	3·745	4·322	4·984	5·743	7·612	10·063	13·268
31	3·914	4·538	5·258	6·087	8·145	10·868	14·462
32	4·09	4·765	5·547	6·453	8·715	11·737	15·763
33	4·274	5·003	5·852	6·84	9·325	12·676	17·182
34	4·466	5·253	6·174	7·25	9·978	13·69	18·728
35	4·667	5·516	6·513	7·685	10·676	14·785	20·414
36	4·877	5·792	6·872	8·147	11·423	15·968	22·251
37	5·097	6·081	7·25	8·635	12·223	17·246	24·254
38	5·326	6·385	7·649	9·154	13·079	18·625	26·437
39	5·566	6·705	8·069	9·703	13·994	20·115	28·816
40	5·816	7·04	8·513	10·286	14·974	21·724	31·409

TABLE I.

Years.	Rates.						
	1 %	1 1/2 %	2 %	2 1/2 %	3 %	3 1/2 %	4 %
41	1·504	1·841	2·252	2·752	3·36	4·098	4·993
42	1·519	1·869	2 297	2·821	3·461	4·241	5·193
43	1·534	1·897	2·343	2·891	3·564	4·39	5·4
44	1·549	1·925	2·39	2·964	3·671	4·543	5·616
45	1·565	1·954	2·438	3·038	3·782	4·702	5·841
46	1·58	1·983	2·487	3·114	3·895	4·867	6·075
47	1·596	2·013	2·536	3·192	4·012	5·037	6·318
48	1·612	2·043	2·587	3·271	4·132	5·214	6·57
49	1·628	2·074	2·639	3·353	4·256	5·396	6·833
50	1·645	2·105	2·692	3·437	4·384	5·585	7·107
51	1·661	2·137	2·745	3·523	4·515	5·78	7·391
52	1·678	2·169	2·8	3·611	4·651	5·983	7·687
53	1·694	2·201	2·856	3·701	4·79	6·192	7·994
54	1·711	2·234	2·913	3 794	4·934	6·409	8·314
55	1·728	2·268	2·972	3·889	5·082	6·633	8·646
56	1·746	2·302	3·031	3·986	5·235	6·865	8·992
57	1·763	2·336	3 092	4·086	5·392	7·106	9·352
58	1·781	2·371	3·154	4·188	5·553	7·354	9·726
59	1·799	2·407	3·217	4·292	5·72	7·612	10·115
60	1·817	2·443	3·281	4·4	5·892	7·878	10·52
61	1·835	2·48	3·347	4·51	6·068	8·154	10·94
62	1·853	2·517	3·414	4·622	6·25	8·439	11·378
63	1·872	2·555	3·482	4·738	6·438	8·735	11·883
64	1·89	2·593	3·551	4·856	6·631	9·04	12·306
65	1·909	2·632	3·622	4·978	6·83	9·357	12·799
66	1·928	2·671	3·695	5·102	7·035	9·684	13·311
67	1·948	2·712	3·769	5·23	7·246	10·023	13·843
68	1·967	2·752	3·844	5·361	7·463	10·374	14·397
69	1·987	2·794	3·921	5·495	7·687	10·737	14·973
70	2·007	2·835	4	5·632	7·918	11·113	15·572
71	2·027	2·878	4·079	5·773	8·155	11·502	16·194
72	2·047	2·921	4·161	5·917	8·4	11·904	16·842
73	2·068	2·965	4·244	6·065	8·652	12·321	17·516
74	2·088	3·009	4·329	6·217	8·912	12·752	18·217
75	2·109	3·055	4·416	6·372	9·179	13·198	18·945
76	2·13	3·1	4·504	6·531	9·454	13·66	19·703
77	2·151	3·147	4·594	6·695	9·738	14·139	20·491
78	2·173	3·194	4·686	6·862	10·03	14·633	21·311
79	2·195	3·242	4·78	7·034	10·331	15·146	22·163
80	2·217	3·291	4·875	7·21	10·641	15·676	23·05

TABLE I.

YEARS.	RATES						
	4 1/2 %	5 %	5 1/2 %	6 %	7 %	8 %	9 %
41	6·078	7·392	8·981	10·903	16·022	23·462	34·236
42	6·352	7·762	9·475	11·557	17·144	25·339	37·318
43	6·637	8·15	9·996	12·251	18·344	27·367	40·676
44	6·936	8·557	10·546	12·986	19·628	29·556	44·337
45	7·248	8·985	11·126	13·765	21·002	31·92	48·327
46	7·574	9·434	11·738	14·591	22·472	34·474	52·677
47	7·915	9·906	12·384	15·466	24·045	37·232	57·418
48	8·271	10·401	13·065	16·394	25·73	40·21	62·585
49	8·644	10·921	13·784	17·378	27·53	43·427	68·218
50	9·033	11·467	14·542	18·42	29·457	46·902	74·357
51	9·439	12·041	15·342	19·525	31·519	56·654	81·05
52	9·864	12·643	16·186	20·697	33·725	54·706	88·344
53	10·308	13·275	17·076	21·938	36·086	59·083	96·295
54	10·772	13·939	18·015	23·255	38·612	63·809	104·961
55	11·256	14·636	19·006	24·65	41·315	68·914	114·408
56	11·763	15·367	20·051	26·129	44·207	74·427	124·705
57	12·292	16·136	21·154	27·697	47·301	80·381	135·928
58	12·845	16·943	22·317	29·359	50·613	86·812	148·162
59	13·423	17·79	23·545	31·12	54·155	93·757	161·497
60	14·027	18·679	24·840	32·988	57·946	101·257	176·031
61	14·659	19·613	26·206	34·967	62·003	109·357	191·874
62	15·318	20·594	27·647	37·065	66·343	118·106	209·143
63	16·008	21·623	29·168	39·289	70·987	127·555	227·966
64	16·728	22·705	30·772	41·646	75·956	137·759	248·482
65	17·481	23·84	32·464	44·145	81·273	148·78	270·846
66	18·267	25·032	34·25	46·794	86·962	160·682	295·222
67	19·089	26·283	36·134	49·602	93·049	173·537	321·792
68	19·948	27·598	38·121	52·578	99·562	187·42	350·753
69	20·846	28·977	40·218	55·732	106·532	202·413	382·321
70	21·784	30·426	42·43	59·076	113·989	218·606	416·73
71	22·764	31·948	44·764	62·62	121·968	236·094	454·236
72	23·789	33·545	47·226	66·378	130·506	254·982	495·117
73	24·859	35·222	49·823	70·36	139·641	275·381	539·677
74	25·978	36·983	52·563	74 582	149·416	397·411	588·248
75	27·147	38·833	55·454	79·057	159·875	321·204	641·191
76	28·369	40·774	58·504	83·8	171·067	346·9	698·898
77	29·645	42·813	61·722	88 828	183·042	374·653	761·789
78	30·979	44·954	65·117	94·158	195·855	404·625	830·361
79	32·273	47·201	68·698	99·807	209·565	436·995	905·093
80	33·83	49·561	72·476	105·796	224·234	471·955	986·552

TABLE I.

Years.	Rates. 1 %	1 1/2 %	2 %	2 1/2 %	3 %	3 1/2 %	4 %
81	2·239	3·34	4·973	7·39	10·96	16·224	23·972
82	2·261	3·39	5·072	7·575	11·289	16·792	24·931
83	2·284	3·441	5·174	7·764	11·628	17·38	25·928
84	2·307	3·493	5·277	7·958	11·976	17·988	26·965
85	2·33	3·545	5·383	8·157	12·336	18·618	28·044
86	2·353	3·598	5·490	8·361	12·706	19·269	29·165
87	2·377	3·652	5·6	8·57	13·087	19·944	30·332
88	2·4	3·707	5·712	8·784	13·48	20·642	31·545
89	2·424	3·762	5·827	9·004	13·884	21·364	32·807
90	2·449	3·819	5·943	9·229	14·3	22·112	34·119
91	2·473	3·876	6·062	9·46	14·729	22·886	35·484
92	2·498	3·934	6·183	9·696	15·171	23·687	36·903
93	2·523	3·993	6·307	9·938	15·626	24·516	38·38
94	2·548	4·053	6·433	10·187	16·095	25·374	39·915
95	2·574	4·114	6·562	10·442	16·578	26·262	41·511
96	2·599	4·176	6·693	10·703	17·075	27·181	43·172
97	2·625	4·238	6·827	10·97	17·588	28·133	44·899
98	2·651	4·302	6·963	11·244	18·115	29·117	46·695
99	2·678	4·366	7·103	11·526	18·659	30·137	48·562
100	2·705	4·432	7·245	11·814	19·219	31·191	50·505
101	2·732	4·498	7·389	12·109	19·795	32·283	52·525
102	2·759	4·566	7·537	12·412	20·389	33·413	54·626
103	2·787	4·634	7·688	12·722	21·001	34·582	56·811
104	2·815	4·704	7·842	13·04	21·631	35·793	59·084
105	2·843	4·775	7·999	13·366	22·28	37·046	61·447
106	2·871	4·846	8·159	13·7	22·948	38·342	63·905
107	2·9	4·919	8·322	14·043	23·636	39·684	66·461
108	2·929	4·993	8·488	14·394	24·346	41·073	69·119
109	2·958	5·068	8·658	14·754	25·076	42·511	71·884
110	2·988	5·144	8·831	15·123	25·828	43·999	74·76
111	3·018	5·221	9·008	15·501	26·603	45·538	77·75
112	3·048	5·299	9·188	15·888	27·401	47·132	80·86
113	3·078	5·378	9·372	16·285	28·223	48·782	84·094
114	3·109	5·459	9·559	16·692	29·07	50·489	87·458
115	3·14	5·541	9·75	17·11	29·942	52·256	90·957
116	3·172	5·624	9·945	17·537	30·84	54·085	94·595
117	3·203	5·709	10·144	17·976	31·765	55·978	98·389
118	3·235	5·794	10·347	18·425	32·718	57·938	102·314
119	3·268	5·881	10·554	18·886	33·7	59·965	106·406
120	3·3	5·969	10·765	19·358	34·711	62·064	110·663

TABLE I.

YEARS.	RATES.						
	4 1/2 %	5 %	5 1/2 %	6 %	7 %	8 %	9 %
81	35·352	52·039	76·462	112·144	239·931	509·711	1075·341
82	36·943	54·641	80·667	118·872	256·726	550·488	1172·122
83	38·606	57·374	85·104	126·005	274·697	594·527	1277·613
84	40·343	60·242	89·785	133·565	293·926	642·09	1392·598
85	42·158	63·254	94·723	141·579	314·501	693·457	1517·932
86	44·056	66·417	99·933	150·074	336·516	748·933	1654·546
87	46·038	69·738	105·429	159·078	360·072	808·848	1803·455
88	48·11	73·225	111·228	168·623	385·277	873·556	1965·766
89	50·275	76·886	117·346	178·74	412·246	943·44	2142·686
90	52·537	80·73	123·801	189·465	441·103	1018·916	2335·528
91	54·901	84·767	130·61	200·833	471·981	1100·429	2545·724
92	57·372	89·005	137·793	212·883	505·02	1188·464	2774·84
93	59·954	93·455	145·372	225·656	540·371	1283·541	3024·575
94	62·651	98·128	153·368	239·195	578·197	1386·224	3296·787
95	65·471	103·035	161·803	253·547	618·671	1497·122	3593·498
96	68·417	108·186	170·702	268·759	661·978	1616·892	3916·913
97	71·496	113·596	180·091	284·885	708·316	1746·243	4269·435
98	74·713	119·275	189·995	301·978	757·898	1885·942	4653·684
99	78·075	125·239	200·445	320·097	810·951	2036·818	5072·516
100	81·588	131·501	211·469	339·302	867·717	2199·763	5529·042
101	85·26	138·076	223·1	359·66	928·458	2375·744	6026·65
102	89·097	144·98	235·37	381·24	993·45	2565·803	6569·05
103	93·106	152·229	248·315	404·114	1062·991	2771·068	7160·27
104	97·296	159·841	261·972	428·361	1137·4	2992·753	7804·694
105	101·674	167·833	276·381	454·063	1217·018	3232·174	8507·12
106	106·249	176·224	291·581	481·306	1302·209	3490·748	9272·761
107	111·031	185·035	307·619	510·185	1393·364	3770·008	10107·31
108	116·027	194·287	324·538	540·796	1490·899	4071·609	11016·97
109	121·248	204·002	342·388	573·244	1595·262	4397·338	12008·49
110	126·704	214·202	361·219	607·639	1706·93	4749·125	13089·25
111	132·406	224·912	381·088	644·097	1826·416	5129·055	14267·29
112	138·364	236·157	402·048	682·743	1954·265	5539·379	15551·34
113	144·591	247·965	424·16	723·708	2091·063	5982·529	16950·96
114	151·097	260·363	447·489	767·13	2237·438	6461·131	18476·55
115	157·897	273·382	472·101	813·158	2394·059	6978·022	20139·44
116	165·002	287·051	498·066	861·948	2561·643	7536·264	21951·99
117	172·427	301·403	525·459	913·664	2740·958	8139·165	23927·67
118	180·186	316·473	554·358	968·484	2932·825	8790·298	26081·17
119	188·295	332·297	584·848	1026·593	3138·122	9493·522	28428·47
120	196·768	348·912	617·014	1088·188	3357·79	10253	30987·03

TABLE I.

YEARS.	RATES.						
	1 %	1 1/2 %	2 %	2 1/2 %	3 %	3 1/2 %	4 %
121	3·333	6·059	10·98	19·842	35·752	64·236	115·089
122	3·367	6·15	11·2	20·338	36·825	66·484	119·693
123	3·4	6·242	11·424	20·846	37·929	68·811	124·48
124	3·434	6·336	11·653	21·367	39·067	71·219	129·459
125	3·469	6·431	11·886	21·902	40·239	73·112	134·638
126	3·503	6·527	12·124	22·45	41·446	76·292	140·023
127	3·538	6·625	12·366	23·011	42·69	78·962	145·624
128	3·574	6·724	12·613	23·586	43·971	81·726	151·449
129	3·61	6·825	12·866	24·176	45·29	84·586	157·507
130	3·646	6·928	13·123	24·78	46·648	87·546	163·808
131	3·682	7·032	13·385	25·399	48·048	90·611	170·36
132	3·719	7·137	13·653	26·034	49·489	93·782	177·174
133	3·756	7·244	13·926	26·686	50·974	97·064	184·261
134	3·794	7·353	14·204	27·352	52·503	100·462	191·632
135	3·832	7·463	14·489	28·036	54·078	103·997	199·297
136	3·87	7·575	14·778	28·737	55·701	107·617	207·27
137	3·909	7·689	15·074	29·455	57·372	111·384	215·56
138	3·948	7·804	15·375	30·192	59·093	115·282	224·182
139	3·987	7·921	15·683	30·947	60·865	119·317	233·149
140	4·027	8·04	15·996	31·721	62·691	123·493	242·475
141	4·067	8·16	16·316	32·513	64·572	127·815	252·174
142	4·108	8·283	16·642	33·326	66·509	132·289	262·261
143	4·149	8·407	16·976	34·16	68·505	136·919	272·752
144	4·191	8·533	17·315	35·013	70·56	141·711	283·662
145	4·232	8·661	17·662	35·888	72·677	146·671	295·008
146	4·275	8·791	18·014	36·786	74·857	151·804	306·809
147	4·318	8·923	18·375	37·706	77·103	157·117	319·081
148	4·365	9·057	18·742	38·638	79·416	162·616	331·844
149	4·404	9·192	19·117	39·615	81·798	168·308	345·178
150	4·448	9·33	19·5	40·605	84·252	174·199	358·923
160	4·914	10·828	23·77	51·978	113·229	245·729	531·293
170	5·428	12·567	28·975	66·536	152·17	346·625	786·444
180	5·996	14·584	35·321	85·172	204·503	488·948	1164·129
190	6·623	16·926	43·056	109·027	274·835	689·71	1723·191
200	7·316	19·643	52·485	139·564	369·356	972·904	2550·75
210	8·081	22·796	63·98	178·653	496·382	1372·376	3775·727
220	8·927	26·456	77·991	228·691	667·097	1935·873	5588·997

TABLE I.

Years.	RATES.						
	4 1/2 %	5 %	5 1/2 %	6 %	7 %	8 %	9 %
121	205·623	366·358	650·95	1153·479	3592·806	11073 24	33775·87
122	214·876	384·676	686·752	1222·688	3844·335	11959·1	36815·7
123	224·546	403·909	724·523	1296·049	4113·438	12915·83	40129·11
124	234·65	424·105	764·372	1373·812	4401·379	13949·1	43740·73
125	245·21	445·31	806·413	1456·242	4709·476	15065·03	47677·4
126	256·244	467·575	850·765	1543 616	5039·139	16270·23	51968·36
127	267·775	490·954	897·557	1636·233	5391·878	17571·85	56645·51
128	279·825	515·502	946·923	1734·407	5769·309	18977·6	61743·6
129	292·417	541·277	999·004	1838·472	6173·16	20495·81	67300·53
130	306·986	568·341	1053·949	1948·781	6605·281	22135·47	73357·56
131	319·327	596·758	1111·916	2065·708	7067·651	23906·31	79959·74
132	333·696	626 596	1173·072	2189·65	7562·387	25818·81	87156·12
133	348·713	657·926	1237·591	2321·029	8091·754	27884·32	95000·17
134	364·405	690·822	1305·658	2460·291	8658·176	30115·06	103550·2
135	380·803	725·363	1377·47	2607·909	9264·249	32524·27	112869·7
136	397·939	761·631	1453·231	2764·383	9912·746	35136·21	123028
137	415·847	799·713	1533·159	2930·246	10606·64	37936·31	134100·5
138	434·56	839·698	1617·482	3106·061	11349·1	40971·21	146169·5
139	454·115	881·683	1706·444	3292·425	12143·54	44248·91	159324·8
140	474·55	925·767	1800·298	3489·97	12993·59	47788·82	173664·1
141	495·905	972·056	2899·314	3699·368	13903·13	51611·93	189293·8
142	518·22	1020·658	2003·777	3921·33	14876·35	55740·88	206330·3
143	541·545	1071·691	2113·984	4156·61	15917·7	60200·15	224900
144	565·91	1125·276	2230·254	4406·007	17031·94	65016·16	245141
145	591·376	1181·54	1352·918	4670·371	18224·17	70217·46	267203·7
146	617·988	1240 617	2482·328	4950·593	19499·87	75834·86	291252
147	645·797	1302·648	2618·856	5247·629	20864·86	81901·65	317464·7
148	674·858	1367·78	2762·894	5562·487	22325·4	88453·78	346036·5
149	705·227	1436·169	2914·853	5896·236	23888·17	95530·08	377179·8
150	736·962	1507·977	3075·17	6250·007	25560·31	103172·5	411126
160	1144·475	2456·336	5252·953	11192·81	50281	222743	973285
170	1777·335	4001·113	8972·596	20044·62	98910	480883	2304119
180	2760·147	6517·392	15326·49	35896·86	194572	1038190	5454690
190	4286·424	10616·14	26179·86	64285·84	382753	2241374	12913527
200	6656·686	17292·58	44718·99	115126	752932	4838960	30570321
210	10337·62	28167·79	76386·49	206173	1481132	10446950	72371067
220	16054	45882·36	130479	369225	2913611	22554188	171328632

TABLE II.

GIVING THE EXPANSION OF THE FACTOR

$$\frac{1}{(1 + t)^{m}}$$

FOR DIFFERENT AGES m AND AT DIFFERENT RATES t,

FOR 1 UNIT.

This table gives the factor by which a sum, to be realised at the expiration of a given number of years m, must be multiplied to obtain its present value.

Note.—Table II is derived from table I, its factors being obtained by dividing 1 by the corresponding figures in table I. It will be sufficient, therefore, to give the rates most in requisition. When, exceptionally, supplementary figures are desired, it will not be asking much if this simple division is left to the user.

TABLE II.

Years.	Rates.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
1	0·98	0·976	0·971	0·966	0·961	0·957	0·952
2	0·961	0·952	0·943	0·933	0·925	0·916	0·907
3	0·942	0·929	0·915	0·902	0·889	0·876	0·864
4	0·924	0·906	0·888	0·871	0·855	0·839	0·823
5	0·906	0·884	0·863	0·842	0·822	0·802	0·783
6	0·888	0·862	0·837	0·813	0·79	0·768	0·746
7	0·871	0·841	0·813	0·786	0·76	0·735	0·711
8	0·853	0·821	0·789	0·759	0·731	0·703	0·677
9	0·837	0·801	0·766	0·734	0·703	0·673	0·645
10	0·82	0·781	0·744	0·709	0·676	0·644	0·614
11	0·804	0·762	0·722	0·685	0·65	0·616	0·585
12	0·788	0·744	0·701	0·662	0·625	0·59	0·557
13	0·773	0·725	0·681	0·639	0·601	0·564	0·53
14	0·758	0·708	0·661	0·618	0·577	0·54	0·505
15	0·743	0·69	0·642	0·597	0·555	0·517	0·481
16	0·728	0·674	0·623	0·577	0·534	0·494	0·458
17	0·714	0·657	0·605	0·557	0·513	0·473	0·436
18	0·7	0·641	0·587	0·538	0·494	0·453	0·415
19	0·686	0·625	0·57	0·52	0·475	0·433	0·396
20	0·673	0·61	0·554	0·503	0·456	0·415	0·377
21	0·66	0·595	0·537	0·486	0·439	0·397	0·359
22	0·647	0·581	0·522	0·469	0·422	0·38	0·342
23	0·634	0·567	0·507	0·453	0·406	0·363	0·326
24	0·622	0·553	0·492	0·438	0·39	0·348	0·31
25	0·609	0·539	0·478	0·423	0·375	0·333	0·295
26	0·598	0·526	0·464	0·409	0·361	0·318	0·281
27	0·586	0·513	0·45	0·395	0·347	0·305	0·268
28	0·574	0·501	0·437	0·382	0·333	0·292	0·255
29	0·563	0·489	0·424	0·369	0·321	0·279	0·243
30	0·552	0·477	0·412	0·356	0·308	0·267	0·231
31	0·541	0·465	0·4	0·344	0·296	0·225	0·22
32	0·531	0·454	0·388	0·333	0·285	0·244	0·21
33	0·52	0·443	0·377	0·321	0·274	0·234	0·2
34	0·51	0·432	0·366	0·31	0·264	0·224	0·19
35	0·5	0·421	0·355	0·3	0·253	0·214	0·181
36	0·49	0·411	0·345	0·29	0·244	0·205	0·173
37	0·481	0·401	0·335	0·28	0·234	0·196	0·164
38	0·471	0·391	0·325	0·271	0·225	0·188	0·157
39	0·462	0·382	0·316	0·261	0·217	0·18	0·149
40	0·453	0·372	0·307	0·253	0·208	0·172	0·142

TABLE II.

Years.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5%
41	0·444	0·363	0·298	0·244	0·2	0·164	0·135
42	0·435	0·354	0·289	0·236	0·193	0·157	0·129
43	0·427	0·346	0·28	0·228	0·185	0·151	0·123
44	0·418	0·337	0·272	0·22	0·178	0·144	0·117
45	0·41	0·329	0·264	0·213	0·171	0·138	0·111
46	0·402	0·321	0·257	0·205	0·165	0·132	0·106
47	0·394	0·313	0·249	0·198	0·158	0·126	0·101
48	0·386	0·306	0·242	0·192	0·152	0·121	0·0961
49	0·379	0·298	0·235	0·185	0·146	0·116	0·0916
50	0·371	0·291	0·228	0·179	0·141	0·111	0·0872
51	0·364	0·284	0·221	0·173	0·135	0·106	0·083
52	0·357	0·277	0·215	0·167	0·13	0·101	0·0791
53	0·35	0·27	0·209	0·161	0·125	0·097	0·0753
54	0·343	0·264	0·203	0·156	0·12	0·0928	0·0717
55	0·336	0·257	0·197	0·151	0·116	0·0888	0·0683
56	0·33	0·251	0·191	0·146	0·111	0·085	0·0651
57	0·323	0·245	0·185	0·141	0·107	0·0813	0·062
58	0·317	0·239	0·18	0·136	0·103	0·0778	0·059
59	0·311	0·233	0·175	0·131	0·0989	0·0745	0·0562
60	0·305	0·227	0·17	0·127	0·0951	0·0713	0·0535
61	0·299	0·222	0·165	0·123	0·0914	0·0682	0·051
62	0·293	0·216	0·16	0·118	0·0879	0·0653	0·0486
63	0·287	0·211	0·155	0·114	0·0845	0·0625	0·0462
64	0·282	0·206	0·151	0·111	0·0813	0·0598	0·044
65	0·276	0·201	0·146	0·107	0·0781	0·0572	0·0419
66	0·271	0·196	0·142	0·103	0·0751	0·0547	0·0399
67	0·265	0·191	0·138	0·0998	0·0722	0·0524	0·038
68	0·26	6·186	0·134	0·0964	0·0695	0·0501	0·0362
69	0·255	0·182	0·13	0·0931	0·0668	0·048	0·0345
70	0·25	0·178	0·126	0·09	0·0642	0·0459	0·0329
71	0·245	0·173	0·123	0·0869	0·0617	0·0439	0·0313
72	0·24	0·169	0·119	0·084	0·0594	0·042	0·0298
73	0·236	0·165	0·116	0·0812	0·0571	0·0402	0·0284
74	0·231	0·161	0·112	0·0784	0·0549	0·0385	0·027
75	0·226	0·157	0·109	0·0758	0·0528	0·0368	0·0257
76	0·222	0·153	0·106	0·0732	0·0507	0·0352	0·0245
77	0·218	0·149	0·103	0·0707	0·0488	0·0337	0·0234
78	0·213	0·146	0·0997	0·0683	0·0469	0·0323	0·0222
79	0·209	0·142	0·0968	0·066	0·0451	0·0309	0·0212
80	0·205	0·139	0·094	0·0638	0·0434	0·0296	0·0202

TABLE II.

Years.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
81	0·201	0·135	0·0912	0·0616	0·0417	0·0283	0·0192
82	0·197	0·132	0·0886	0·0595	0·0401	0·0271	0·0183
83	0·193	0·129	0·086	0·0575	0·0386	0·0259	0·0174
84	0·189	0·126	0·0835	0·0556	0·0371	0·0248	0·0166
85	0·186	0·123	0·0811	0·0537	0·0357	0·0237	0·0158
86	0·182	0·12	0·0787	0·0519	0·0343	0·0227	0·0151
87	0·179	0·117	0·0764	0·0501	0·033	0·0217	0·0143
88	0·175	0·114	0·0742	0·0484	0·0317	0·0208	0·0137
89	0·172	0·111	0·072	0·0468	0·0305	0·0199	0·013
90	0·168	0·108	0·0699	0·0452	0·0293	0·019	0·0124
91	0·165	0·106	0·0679	0·0437	0·0282	0·0182	0·0118
92	0·162	0·103	0·0659	0·0422	0·0271	0·0174	0·0112
93	0·159	0·101	0·064	0·0408	0·0261	0·0167	0·0107
94	0·155	0·0982	0·0621	0·0394	0·025	0·016	0·0102
95	0·152	0·0958	0·0603	0·0381	0·0241	0·0153	0·0097
96	0·149	0·0934	0·0586	0·0368	0·0232	0·0146	0·0092
97	0·146	0·0912	0·0569	0·0355	0·0223	0·014	0·0088
98	0·144	0·0889	0·0552	0·0343	0·0214	0·0134	0·0084
99	0·141	0·0868	0·0536	0·0332	0·0206	0·0128	0·008
100	0·138	0·0846	0·052	0·0321	0·0198	0·0123	0·0076
101	0·135	0·0826	0·0505	0·031	0·019	0·0117	0·0072
102	0·133	0·0801	0·049	0·0299	0·0183	0·0112	0·0069
103	9·13	0·0786	0·0476	0·0289	0·0176	0·0107	0·0066
104	0·127	0·0767	0·0462	0·0279	0·0169	0·0103	0·0063
105	0·125	0·0748	0·0449	0·027	0·0163	0·0098	0·006
106	0·123	0·073	0·0436	0·0261	0·0156	0·0094	0·0057
107	0·12	0·0712	0·0423	0·0252	0·015	0·009	0·0054
108	0·118	0·0695	0·0411	0·0243	0·0145	0·0086	0·0051
109	0·115	0·0678	0·0399	0·0235	0·0139	0·0082	0·0049
110	0·113	0·0661	0·0387	0·0227	0·0134	0·0079	0·0047
111	0·111	0·0645	0·0376	0·022	0·0129	0·0075	0·0044
112	0·108	0·0629	0·0365	0·0212	0·0124	0·0072	0·0042
113	0·107	0·0614	0·0354	0·0205	0·0119	0·0069	0·004
114	0·105	0·0599	0·0344	0·0198	0·0114	0·0066	0·0038
115	0·103	0·0584	0·0334	0·0191	0·011	0·0063	0·0037
116	0·1	0·057	0·0324	0·0185	0·0106	0·0061	0·0035
117	0·0986	0·0556	0·0315	0·0179	0·0102	0·0058	0·0033
118	0·0966	0·0542	0·0306	0·0173	0·0098	0·0055	0·0032
119	0·0947	0·0529	0·0297	0·0167	0·0094	0·0053	0·003
120	0·0929	0·0517	0·0288	0·0161	0·009	0·0051	0·0029

TABLE II.

Years.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
121	0·0911	0·0504	0·028	0·0156	0·0087	0·0049	0·0027
122	0·0893	0·0492	0·0272	0·015	0·0083	0·0046	0·0026
123	0·0875	0·048	0·0264	0 0145	0·008	0·0044	0·0025
124	0·0858	0·0468	0·0256	0·014	0·0077	0 0043	0·0024
125	0·0841	0·0457	0·0248	0·0136	0 0074	0·0041	0·0022
126	0·0825	0·0445	0·0241	0·0131	0·0071	0·0039	0·0021
127	0·0809	0·0435	0·0234	0·0127	0·0069	0·0037	0·002
128	0·0793	0·0424	0·0227	0·0122	0·0066	0·0036	0·0019
129	0·0777	0·0414	0·0221	0·0118	0·0063	0 0034	0·0018
130	0·0762	0·0403	0·0214	0·0114	0·0061	0·0033	0·0018
131	0·0747	0·0394	0·0208	0·011	0·0059	0·0031	0·0017
132	0·0732	0·0384	0·0202	0·0107	0·0056	0·003	0·0016
133	0·0718	0·0375	0·0196	0·0103	0·0054	0·0029	0·0015
134	0·0704	0·0366	0·019	0·01	0·0052	0·0027	0·0014
135	0·069	0·0357	0·0185	0·0096	0·005	0·0026	0·0014
136	0·0677	0·0348	0·0179	0·0093	0·0048	0·0025	0·0013
137	0·0663	0·0339	0·0174	0·009	0·0046	0·0024	0·0012
138	0·065	0·0331	0·0169	0·0087	0·0045	0·0023	0·0012
139	0·0638	0·0323	0·0164	0·0084	0·0043	0·0022	0·0011
140	0·0625	0·0315	0·016	0·0081	0·0041	0·0021	0·0011
141	0·0613	0·0308	0·0155	0·0078	0·004	0 002	0·001
142	0·0601	0·03	0·015	0·0076	0·0038	0·0019	0·001
143	0·0589	0·0293	0·0146	0·0073	0·0037	0·0018	0·0009
144	0·0577	0·0286	0·0142	0·0071	0·0035	0·0018	0·0009
145	0·0566	0·0279	0·0138	0·0068	0·0034	0·0017	0·0008
146	0·0555	0·0272	0·0134	0·0066	0·0033	0·0016	0·0008
147	0·0544	0·0265	0·013	0·0064	0·0031	0·0015	0·0008
148	0·0533	0·0259	0·0126	0·0061	0·003	0·0015	0·0007
149	0·0523	0·0252	0·0122	0·0059	0·0029	0·0014	0·0007
150	0·0513	0·0246	0·0119	0·0057	0·0028	0·0014	0·0007
160	0·0421	0·0192	0·0088	0·0041	0·0019	0·0009	0·00041
170	0·0345	0·015	0·0066	0·0029	0·0013	0·0006	0·00025
180	0·0283	0·0117	0·0049	0·002	0·0009	0·0004	0·00015
190	0·0232	0·0092	0·0036	0·0014	0·0006	0·0002	0·00009
200	0·019	0·0072	0·0027	0·0001	0·0004	0·0001	0·00006

TABLE III.

GIVING THE EXPANSION OF THE FACTOR

$$\frac{1}{(1 + t)^n - 1}$$

FOR DIFFERENT AGES n AND AT DIFFERENT RATES t

FOR 1 UNIT.

This table gives the factor by which a sum or revenue, realised at equal intervals n, must be multiplied to obtain the actual corresponding capital.

Note.—The factors of this table are obtained by dividing 1 by the corresponding figures of table I minus 1. It will, therefore, be sufficient to give the factors for the rates most in use. If further factors are required, a subtraction followed by a simple division is all that is necessary.

TABLE III.

YEARS.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
1	50	40	33·333	28·571	25	22·222	20
2	24·752	19·753	16·42	14·04	12·255	10 867	9·756
3	16·338	13·005	10·784	9·198	8·009	7·084	6 344
4	12·131	9·633	7·968	6·779	5·887	5·194	4·64
5	9·608	7·61	6·278	5·328	4·616	4·062	3·619
6	7·926	6·262	5·153	4·362	3·769	3·308	2·94
7	6·726	5·3	4·35	3·673	3·165	2·771	2·456
8	5·825	4·579	3·748	3·156	2·713	2·369	2·094
9	5·126	4·018	3·281	2·756	2·462	2·057	1·814
10	4·566	3·57	2·908	2·435	2·082	1·808	1·59
11	4·109	3·204	2·603	2·174	1·854	1·605	1·408
12	3·728	2·899	2·349	1·957	1·664	1·437	1·256
13	3·406	2·642	2·134	1·773	1·504	1 295	1·129
14	3·13	2·431	1·951	1·616	1·367	1·174	1·02
15	2·891	2·231	1·792	1·481	1·248	1·069	0·927
16	2·682	2·064	1·654	1·362	1·145	0·978	0·845
17	2·498	1·917	1·532	1 258	1·055	0·898	0·774
18	2·335	1·787	1·424	1·166	0·975	0·827	0·711
19	2·189	1·67	1·327	1·084	0·903	0·765	0·655
20	2·058	1·566	1·24	1·01	0·839	0·708	0·605
21	1·939	1·471	1·162	0·944	0·782	0·658	0·56
22	1·832	1·386	1·092	0·884	0·73	0·612	0·519
23	1·733	1·308	1·027	0·829	0 683	9·571	0·483
24	1·644	1·236	0·968	0·779	0·64	0·533	0·449
25	1·561	1·171	0·914	0·733	0·6	0·499	0·419
26	1·485	1·111	0·865	0·692	0·564	0·467	0·391
27	1·415	1·055	0·819	0·653	0·531	0 438	0·366
28	1·346	1·003	0·776	0·617	0·5	0·412	0·342
29	1·289	0·956	0·737	0 584	0·472	0·387	0·321
30	1·232	0·911	0·701	0·553	0·446	0·364	0·301
31	1·18	0·87	0·667	0·525	0·421	0·343	0·283
32	1·13	0·831	0·635	0·498	0·399	0·324	0·266
33	1·084	0·794	0·605	0·473	0·378	0·305	0·25
34	1·041	0·76	0·577	0·45	0·358	0·288	0·235
35	1	0·728	0·551	0·428	0·339	0·273	0·221
36	0·962	0·698	0·527	0·408	0·322	0·258	0·209
37	0·925	0·67	0·504	0·389	0 306	0·244	0·197.
38	0·891	0·643	0·482	0·371	0·291	0·231	0·186
39	0·859	0·617	0·461	0 354	0·276	0·219	0·175
40	0·828	0·593	0·442	0·338	0·263	0·208	0·166

TABLE III.

YEARS.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
41	0·799	0·571	0·424	0·323	0·25	0·197	0·156
42	0·771	0·549	0·406	0·308	0·238	0·187	0·148
43	0·744	0·529	0·39	0·295	0·227	0·177	0·14
44	0·719	0·509	0·374	0·282	0·217	0·168	0·132
45	0·695	0·491	0·359	0·27	0·207	0·16	0·125
46	0·673	0·473	0·345	0·259	0·197	0·152	0·119
47	0·651	0·456	0·332	0·248	0·188	0·145	0·112
48	0·63	0·44	0·319	0·237	0·179	0·137	0·106
49	0·61	0·425	0·307	0·227	0·171	0·131	0·101
50	0·591	0·41	0·295	0·218	0·164	0·124	0·0955
51	0·573	0·396	0·284	0·209	0·156	0·118	0·0906
52	0·555	0·383	0·274	0·201	0·15	0·113	0·0859
53	0·539	0·37	0·264	0·193	0·143	0·107	0·0815
54	0·523	0·358	0·254	0·185	0·137	0·102	0·0773
55	0·507	0·346	0·245	0·177	0·131	0·0975	0·0733
56	0·492	0·335	0·236	0·17	0·125	0·0929	0·0696
57	0·478	0·324	0·228	0·164	0·12	0·0886	0·0661
58	0·464	0·314	0·22	0·157	0·115	0·0844	0·0627
59	0·451	0·304	0·212	0·151	0·11	0·0805	0·0596
60	0·438	0·294	0·204	0·145	0·105	0·0768	0·0566
61	0·426	0·285	0·197	0·14	0·101	0·0732	0·0537
62	0·414	0·276	0·19	0·134	0·0964	0·0698	0·051
63	0·403	0·267	0·184	0·129	0·0923	0·0666	0·0485
64	0·392	0·259	0·178	0·124	0·0884	0·0636	0·0461
65	0·381	0·251	0·171	0·12	0·0848	0·0607	0·0438
66	0·371	0·244	0·166	0·115	0·0812	0·0579	0·0416
67	0·361	0·236	0·16	0·111	0·0779	0·0553	0·0395
68	0·352	0·229	0·155	0·107	0·0746	0·0528	0·0376
69	0·342	0·222	0·149	0·103	0·0716	0·0504	0·0357
70	0·333	0·216	0·145	0·0989	0·0686	0·0481	0·034
71	0·325	0·209	0·14	0·0952	0·0658	0·0459	0·0323
72	0·316	0·203	0·135	0·0917	0·0631	0·0439	0·0307
73	0·308	0·197	0·131	0·0883	0·0605	0·0419	0·0292
74	0·3	0·192	0·126	0·0851	0·0581	0·04	0·0278
75	0·293	0·186	0·122	0·082	0·0557	0·0382	0·0264
76	0·285	0·181	0·118	0·079	0·0535	0·0365	0·0251
76	0·278	0·176	0·114	0·0761	0·0513	0·0349	0·0239
78	0·271	0·171	0·111	0·0733	0·0492	0·0334	0·022
79	0·265	0·166	0·107	0·0707	0·0472	0·0319	0·0216
80	0·258	0·161	0·104	0·0681	0·0453	0·0305	0·0206

TABLE III.

Years.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
81	0·252	0·156	0·01	0·0657	0·0435	0·0291	0·0196
82	0·246	0·152	0·0972	0·0633	0·0418	0·0278	0·0186
83	0·24	0·148	0·0941	0·061	0·0401	0·0266	0·0177
84	0·234	0·144	0·0911	0·0589	0·0385	0·0254	0·0169
85	0·228	0·14	0·0882	0·0568	0·037	0·0243	0·0161
86	0·223	0·136	0·0854	0·0547	0·0355	0·0232	0·0153
87	0·217	0·132	0·0827	0·0528	0·0341	0·0222	0·0145
88	0·212	0·128	0·0801	0·0509	0·0327	0·0212	0·0138
89	0·207	0·125	0·0776	0·0491	0·0314	0·0203	0·0132
90	0·202	0·121	0·0752	0·0474	0·0302	0·0194	0·0025
91	0·197	0·118	0·0728	0·0457	0·029	0·0185	0·0119
92	0·193	0·115	0·0706	0·0441	0·0278	0·0177	0·0114
93	0·188	0·112	0·0684	0·0425	0·0267	0·017	0·0108
94	0·184	0·109	0·0662	0·041	0·0257	0·0162	0·0103
95	0·18	0·106	0·0642	0·0396	0·0247	0·0155	0·0098
96	0·176	0·103	0·0622	0·0382	0·0237	0·0148	0·0093
97	0·172	0·1	0·0603	0·0369	0·0228	0·0142	0·0089
98	0·168	0·0976	0·0584	0·0356	0·0219	0·0136	0·0084
99	0·164	0·095	0·0566	0·0343	0·021	0·013	0·008
100	0·16	0·0925	0·0549	0·0331	0·0202	0·0124	0·0077
101	0·156	0·09	0·0532	0·032	0·0194	0·0119	0·0073
102	0·153	0·0876	0·0516	0·0308	0·0186	0·0113	0·0069
103	0·149	0·0853	0·05	0·0298	0·0179	0·0109	0·0066
104	0·146	0·0831	0·0485	0·0287	0·0172	0·0104	0·0063
105	0·143	0·0809	0·047	0·0277	0·0165	0·0099	0·006
106	0·14	0·0787	0·0456	0·0268	0·0159	0·0095	0·0057
107	0·137	0·0767	0·0442	0·0258	0·0153	0·0091	0·0054
108	0·133	0·0747	0·0428	0·0249	0·0147	0·0087	0·0052
109	0·131	0·0727	0·0415	0·0241	0·0141	0·0083	0·0049
110	0·128	0·0708	0·0403	0·0233	0·0136	0·0079	0·0047
111	0·125	0·069	0·0391	0·0224	0·013	0·0076	0·0045
112	0·122	0·0672	0·0379	0·0217	0·0125	0·0073	0·0042
113	0·119	0·0654	0·0367	0·0209	0·012	0·007	0·004
114	0·117	0·0637	0·0356	0·0202	0·0116	0·0067	0·0039
115	0·114	0·0621	0·0345	0·0195	0·0111	0·0064	0·0037
116	0·112	0·0605	0·0335	0·0188	0·0107	0·0061	0·0035
117	0·109	0·0589	0·0325	0·0182	0·0103	0·0058	0·0033
118	0·107	0·0574	0·0315	0·0176	0·0099	0·0056	0·0032
119	0·105	0·0559	0·0306	0·017	0·0095	0·0053	0·003
120	0·102	0·0545	0·0297	0·0164	0·0091	0·0051	0·0029

TABLE III.

Years.	RATES.						
	2 %	2 1/2 %	3 %	3 1/2 %	4 %	4 1/2 %	5 %
121	0·1	0·0531	0·0288	0·0158	0·0088	0·0049	0·0027
122	0·098	0·0517	0·0279	0·0153	0·0084	0·0047	0·0026
123	0·0959	0·0504	0·0271	0·0147	0·0081	0·0045	0·0025
124	0·0939	0·0491	0·0263	0·0142	0·0078	0·0043	0·0024
125	0·0919	0·0478	0·0255	0·0139	0·0075	0·0041	0·0022
126	0·0899	0·0466	0·0248	0·0133	0·0072	0·0039	0·0021
127	0·088	0·0454	0·024	0·0128	0·0069	0·0037	0·002
128	0·0861	0·0443	0·0233	0·0124	0·0066	0·0036	0·0019
129	0·0843	0·0431	0·0226	0·012	0·0064	0·0034	0·0018
130	0·0825	0·042	0·0219	0·0115	0·0061	0·0033	0·0018
131	0·0807	0·041	0·0212	0·0112	0·0059	0·0031	0·0017
132	0·079	0·0399	0·0206	0·0108	0·0057	0·003	0·0016
133	0·0774	0·0389	0·02	0·0104	0·0055	0·0029	0·0015
134	0·0757	0·0379	0·0194	0·01	0·0052	0·0027	0·0014
135	0·0743	0·037	0·0188	0·0097	0·005	0·0026	0·0014
136	0·0726	0·036	0·0183	0·0094	0·0048	0·0025	0·0013
137	0·071	0·0351	0·0177	0·0091	0·0047	0·0024	0·0012
138	0·0696	0·0342	0·0172	0·0087	0·0045	0·0023	0·0012
139	0·0681	0·0334	0·0167	0·0084	0·0043	0·0022	0·0011
140	0·0667	0·0325	0·0162	0·0082	0·0041	0·0021	0·0011
141	0·0653	0·0317	0·0157	0·0079	0·004	0·002	0·001
142	0·0639	0·0309	0·0153	0·0076	0·0038	0·0019	0·001
143	0·0626	0·0301	0·0148	0·0074	0·0037	0·0018	0·0009
144	0·0613	0·0294	0·0144	0·0071	0·0035	0·0018	0·0009
145	0·0	0·0287	0·0139	0·0069	0·0034	0·0017	0·0008
146	0·0588	0·0279	0·0135	0·0066	0·0033	0·0016	0·0008
147	0·0576	0·0271	0·0131	0·0064	0·0031	0·0015	0·0008
148	0·0564	0·0266	0·0127	0·0062	0·003	0·0015	0·0007
149	0·0552	0·0259	0·0124	0·006	0·0029	0·0014	0·0007
150	0·0541	0·0252	0·012	0·0057	0·0028	0·0014	0·0007
160	0·0439	0·0196	0·0089	0·0041	0·0019	0·0009	0·00041
170	0·0357	0·0153	0·0066	0·0029	0·0013	0·0006	0·00025
180	0·0291	0·0119	0·0049	0·002	0·0009	0·0004	0·00015
190	0·0238	0·0093	0·0036	0·0014	0·0006	0·0002	0·00009
200	0·0194	0·0072	0·0027	0·001	0·0004	0·0001	0·00006

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